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CHAPTER 4 SUPERSTRUCTURE

SECTION 4.1 INTRODUCTION

For bridge inspection purposes, superstructure refers to all structural members, other than the deck, that distribute loads to the substructure units. One exception to this definition is a reinforced concrete slab, where the deck and superstructure are one and the same. Figure 4:4-1 shows cross sections for many common superstructure types:

- (A) Reinforced Concrete Slab
- (B) Reinforced Concrete Voided Slab
- (C) Timber Slab
- (D) Steel Multi-Beam
- (E) Steel Through Girder
- (F) Steel Girder/Floor Beam/Stringer
- (G) Reinforced Concrete Girder (T-Beam)
- (H) Prestressed Concrete I-Beam
- (I) Precast Concrete Channel Beam
- (J) Prestressed Concrete Box Beam
- (K) Steel Box Girder
- (L) Post-Tensioned Concrete Box Girder
- (M) Reinforced Concrete Through Girder
- (N) Timber Multi-Beam
- (O) Steel Truss
- (P) Timber Truss

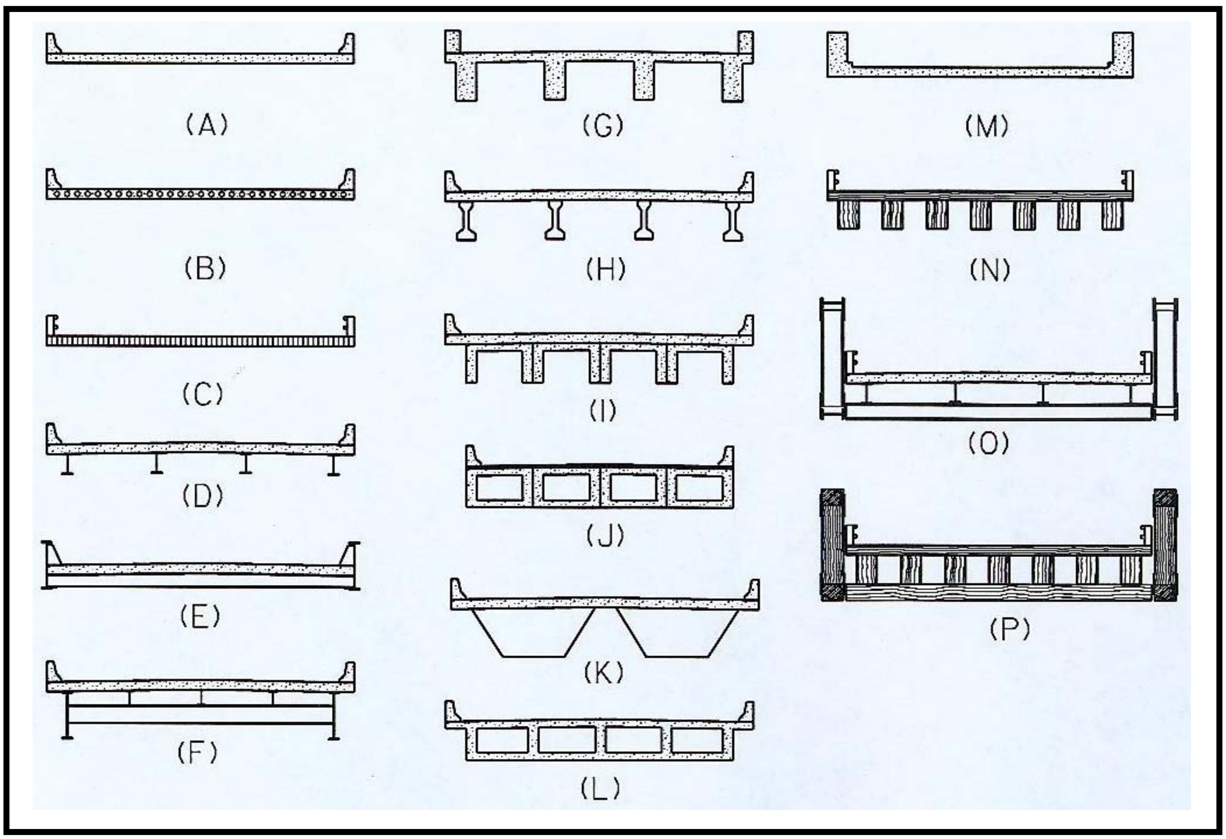


Figure 4:4-1: Common Superstructure Types

Superstructure members are categorized into two groups: primary and secondary. Primary superstructure members are those that directly carry the deck dead loads and live loads to the substructure. Primary superstructure members include girders, beams, stringers, arches, trusses, cables, bearings, and bearing stiffeners. Primary superstructure members must carry repetitive live loads, as well as repeatedly applied impact loads.

Secondary superstructure members provide lateral stability for the primary members and help laterally distribute the live loads so that the primary members act together as a unit. Secondary members include diaphragms, cross-frames, sway bracing, lateral bracing, transverse web stiffeners, and longitudinal web stiffeners.

Depending on the type of superstructure, the members may need to deliver these loads to the substructure by way of bending, tension, compression, or a combination of these. To handle this type of demand, it is critical that the members be sound, as any failure of a member could be catastrophic. This chapter provides guidelines for the bridge inspector on which parts of the superstructure are critical to inspect and what defects may cause future problems.

Figure 4:4-2: Through Arch Truss Bridge

SECTION 4.2 STEEL SUPERSTRUCTURES

Since the late 1800s, steel has been one of the most commonly used materials for the construction of bridge superstructures. It can be designed to carry tension, compression, and bending loads. Steel can be configured in many different ways and can be used to create virtually any bridge type, including multi-beam bridges, two-girder bridges, arches, rigid frame bridges, trusses, and box girder bridges.

The most common defect found on steel superstructures is corrosion, and the worst corrosion is generally found where the steel is subjected to cycles of moisture. Corrosion reduces the section of a member, leading to an increase in stress. Corrosion can also affect how a structure operates. For example, unintended bending stresses may be introduced to a member when corroded pins restrict movement. In order to check for corrosion, inspectors must remove local areas of debris accumulation. Dirt and debris on members trap moisture and road salts and increase corrosion. Bird waste is acidic and traps moisture and road salts, accelerating corrosion. Figure 4:4-3 shows corrosion on a girder flange.

Figure 4:4-3: Pitting Caused by Corrosion on Girder Bottom Flange

Pack rust is corrosion occurring between two pieces of lapped steel, such as between the vertical leg of a flange angle and the girder web. These details trap moisture and do not allow for quick water evaporation; so, pack rust most often occurs under leaking drains or expansion joints, at fascia girders, and on trusses and arches. The expansive force of pack rust can be great enough to bend thick plates and to pry and fracture rivets and bolts. Details prone to pack rust include girder flange and web splices, gusset plates, riveted cover plates, and back-to-back angles. Figure 4:4-4 shows corrosion on a girder flange.

Figure 4:4-4: Pack Rust Prying Apart Flange Splice Plates

Bridges constructed with weathering steel are also susceptible to corrosion. The signs of corrosion on weathering steel include deep pitting, laminar rust, flaking, or a rough surface.

Steel structures are also susceptible to developing fatigue cracks. Fatigue failure is of special concern because fatigue failures can be brittle, giving no warning as to imminent collapse. When steel is welded, the stress from the weld can create a crack. Certain details, especially those where welds intersect or where the steel is constrained in more than one direction, are especially prone to cracking. Appendix A shows several illustrative examples of fatigue-prone details. All welds must be carefully examined because poor welding may have left flaws within the weld metal even where fatigue cracks are not normally expected to be found. Fatigue cracks usually show up as rust stains or rusty breaks in the paint, propagating perpendicular to the direction of stress. Detection of fatigue cracks will most often occur during arm's length inspections. See Part 4, Chapter 11 for more information on Fatigue and Fracture Critical Inspections.

Subsection 4.2.1 Beam and Girder Bridges

Beam and girder bridges are constructed using hot rolled steel beams or fabricated girders including fabricated box girders. These shapes can be used to construct multi-beam bridges, two-girder bridges, or single-girder bridges when using box beam construction.

- **Rolled Multi-Beam Bridges:** Rolled multi-beam bridges are constructed using three or more hot-rolled steel beams as the primary members. Beam depths are usually no more than 36 inches, which limits spans to about 90 feet. Transverse diaphragm secondary members, using C-shaped channel sections or I-shaped members, may be bolted, riveted, or welded with intermittent welds to the beam webs. To increase a beam's bending capacity, cover plates may be riveted, bolted, or welded to the tension and/or compression flanges.

Figure 4:4-5: Rolled Steel Multi-Beam Bridge

- **Fabricated Multi-Girder Bridges:** Fabricated multi-girder bridges are constructed using three or more built-up steel girders as the primary members. The girders are fabricated by either riveting or bolting steel plates and sections, or by welding steel plates. Greater economy is typically achieved by varying flange thickness/width or the number of plates in a flange to accommodate the bending moment. Web depths may also be deepened (haunched) over the piers to accommodate the bending moment. Girder depths are usually greater than 36 inches, allowing for spans up to about 500 feet. Due to their greater web depths, transverse cross-frames using angles or T-shapes are usually used as secondary members. In addition, vertical and longitudinal stiffeners may be welded or riveted to the web to prevent web buckling. Older structures may use lateral bracing placed at the level of the bottom or top girder flanges to connect adjacent girders. Larger spans may be built with a floor system consisting of stringers and floor beams as additional primary members. Floor beams are transverse members that frame into the girder webs. The stringers bear on or are framed into the floor beams. Stringers are usually rolled beams placed between, and running parallel to, the girders.

Figure 4:4-6: Fabricated Girders and Cross-Frame Members

- **Fabricated Two-Girder Bridges:** Two-girder system bridges are constructed using only two built-up steel girders as primary members. These bridges have floor systems that use floor beams and sometimes stringers. As in fabricated multi-girder bridges, the girders are fabricated by either riveting/bolting together steel plates and angles, or by welding steel plates together. Two-girder systems do not have load path redundancy and are classified as fracture critical bridges.

Figure 4:4-7: Steel Two-Girder Bridge

- **Steel Through Girder Bridges:** Through girder bridges are fabricated two-girder bridges with the deck placed between the girders rather than on top of them. Many older short- to medium-span highway and railroad bridges use this configuration. Through girder bridges lack redundancy and are fracture critical.

Figure 4:4-8: Steel Through Girder Bridge

Figure 4:4-9: Steel Railroad Flatcar Bridge

- **Railroad Flatcar Bridges:** Railroad flatcar bridges are steel girder bridges constructed from salvaged railroad flatcars. They are available in many configurations. The design and installation of a railroad flatcar bridge should be overseen by an engineer registered in the state of Indiana. Special attention must be given to the selection of the flatcar, the design of the longitudinal connections between flatcars, and load transfer. Most railroad flatcars should be supported on the bolsters and the design engineer should ensure that the support is adequate. Welded connections should be visually inspected to ensure that fatigue cracks are not present when a flatcar is selected for use as a bridge. Box cars and gondola cars should not be used in the construction of bridges.

- **Steel Box Girder Bridges:** Box girder bridges have one or more girders fabricated from plates welded into a rectangular or trapezoidal closed shape. Because closed shapes are more torsionally stiff than open I-shaped girders, box girders are commonly used for curved spans. Closed shapes also help protect the steel from corrosion since only half the plate area is exposed to the elements. The vertical plates form the webs and the bottom plate forms the bottom flange. The top flange is formed by the top plate, if present, or the concrete deck. Both the web and flange plates are normally strengthened with transverse and longitudinal stiffeners to prevent buckling. Box girders can usually be entered through access hatches to allow inspection of their interiors. Bridges using one box girder do not have load path redundancy and are classified as fracture critical bridges. Most two-box girder bridges are also classified as fracture critical. However, some two-box girder bridges have been designed with substantial bracing between the boxes so that one of them can support the entire bridge should the other fail. Steel box girder bridges are considered complex in Indiana. The steel box girders constructed in the 1960s and 1970s often developed cracks due to torsion from improper shipping and erection. These cracks were often found at the web gaps.

Figure 4:4-10: Steel Box Girders

The inspection of steel girder bridges should include the following:

- View down the member's length to check vertical and horizontal alignments and check for any lateral bending or twisting. This type of damage may be due to overloads, corrosion, traffic impact, or support settlement.
- Examine all members and bearings for corrosion and loss of cross-sectional area. Particular attention should be given to the areas below the deck expansion joints and to details that trap water. The inspector should remove as much rust as possible, using a chipping hammer or paint scraper, and record the section loss. Some corrosion is so severe that holes are created through the steel plate. This situation should be recorded as through thickness section loss. If any section loss over 10 percent on a primary member is found, the District Engineer or the Inspection Consultant should be notified and the bridge should be re-rated for load.
- Look for pack rust, noted by individual plate bending between fasteners. The amount of plate separation caused by pack rust should be measured and recorded. Note any deformation of plates.
- Document all cracks. The District Engineer or the Inspection Consultant should be notified of newly discovered cracks in primary steel members. Include dates of when the crack was discovered, confirmed, and re-examined; its location, length, and width; and the location of crack tips. This information should be written directly on the cracked member with a permanent marker or a paint stick on weathering or corroded steel for easy reference and relocation at later dates. Sketches and photographs should be used to indicate the location, orientation, and length. Record the dimensions and details of the member containing the crack, any opening or closing of the crack as vehicles pass, corrosion conditions at the crack, and whether or not dirt or debris is found on the cracked steel surfaces.
- Check rivet/bolt heads on built-up components. Corrosion on the heads may indicate corrosion along the entire fastener length, reducing structural integrity.
- Check all fasteners. Signs of fatigue include rust bleeding/powder under the fastener head or nut, gaps between the connected parts and the fastener head or nut, a dull sound when the head is tapped with a hammer, and missing fasteners.
- Look for overload damage in the form of compression flange buckling and tension flange elongation or fracture.
- Look for web crippling, a permanent wrinkling or buckling of the web due to overloads.
- Look for torsion-related damage on curved box girders at the diaphragms/cross-frames, webs, and flanges as evidenced by plate or member distortions.

- Look for signs of impact damage, including scrapes on member undersides, distorted members, and nicks or gouges on plate edges or member corners. Particularly strong collisions may tear the steel. Impact damage is usually most prominent on the fascia girders, although damage can occur across the entire cross section of the superstructure due to impact and recoil of all members after impact.
- Inspect pins or pin-and-hanger assemblies in accordance with Part 4, 4.2.7.1.
- Inspect cables and rods in accordance with Part 4, 4.2.7.2.
- Inspect pins at eyebars, bearings, hangers (U-bolts), or other devices holding up the floor beams in older trusses.
- Examine the connections between railroad flatcars.
- Note where railroad flatcars are supported. If not supported at the bolsters, recommend that the members be checked for adequate strength and stability in the bearing area.
- Note any pre-installation damage on railroad flatcars and check damaged areas for cracks.
- For railroad flatcar bridges, note areas where original equipment such as mounting brackets and braking equipment have been removed and check for stress risers.
- For railroad flatcar bridges, note if any primary structural components have been modified and check that the load rating reflects the modifications.

Figure 4:4-11: Damaged Steel Flatcar Bridge

Subsection 4.2.2 Steel Truss Bridges

Steel truss bridges are structures with two or more parallel trusses supporting the deck. The deck may be placed on top of the trusses (deck truss) or between the trusses (through truss when there is overhead lateral bracing, or pony truss when there is no overhead lateral bracing). Through or pony trusses are most often constructed using two trusses, and are considered fracture critical structures. Two-truss deck trusses are also fracture critical structures.

Truss chord, diagonal, and vertical members may be fabricated from eyebars, rolled shapes, or built-up members. Connections are made with rivets, bolts, welding, or pin connections in some older trusses. All truss bridges have floor systems similar to two-girder systems. To keep the two trusses in line longitudinally, secondary lateral bracing members diagonally connect the bottom chords. For deck and through trusses, the top chords are laterally braced in a similar way. Sway bracing keeps the two trusses in line laterally. On deck and through trusses, sway bracing transversely frames between the truss verticals. On pony trusses, sway bracing is usually placed as a transverse diagonal on the outside of the trusses. It connects the top chord to transverse outrigger floor beam extensions and prevents buckling of the top chord. Typical components are labeled in Figure 4:4-12.

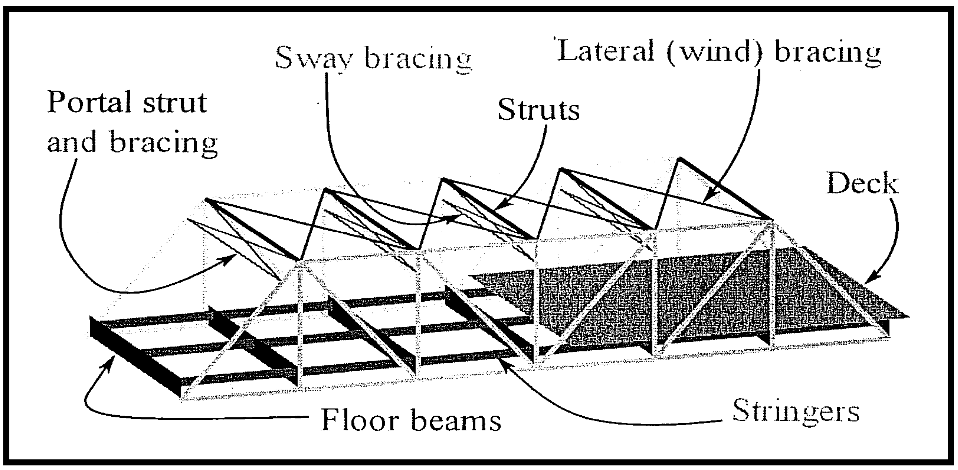


Figure 4:4-12: Truss Components

Truss members are theoretically loaded in either pure tension or compression and are considered to be axially loaded. Members carrying tensile loads are fracture critical members. Though each of these members may contain internal redundancy (multiple eyebars or built-up riveted shapes), each member is inspected as a fracture critical member. Steel through trusses and trusses with pin and eyebar connections are considered complex bridges in Indiana.

Figure 4:4-13: Steel Through Truss Bridge

Tension members must be identified prior to performing a Fracture Critical Inspection. It is also advantageous to identify tension members for a Routine Inspection. On simply supported trusses, the bottom chords will always be in tension and the vertical member closest to each support will always be in tension. On continuous trusses, the top chord will be in tension over the piers, and the bottom chord will be in tension between supports; the bottom chord will be in compression over the piers, and the top chord will be in compression between supports. On simply supported trusses, diagonals that point upward and away from mid-span are tension members, as well as any counters which form an “X” pattern at or near mid-span. There is no easy method to determine which diagonals are in tension for continuously supported trusses and for vertical members of any truss.

Visual methods are not always capable of adequately evaluating the condition of gusset plates with section loss due to corrosion in tightly configured connections, or those where the members framing into the gusset plate are closely spaced. Trusses with these fracture critical connections may require special documentation and nondestructive testing (NDT) to quantify the gusset plate thickness. This is further discussed in detail in Part 4, Chapter 11, Section 11.3.

Figure 4:4-14: Multiple Eyebars Connected With a Pin

Figure 4:4-15: Truss Lower Chord

Note the impact damage on Figure 4:4-15.

Inspection of steel truss bridges should include the following:

- View down the member's length to check vertical and horizontal alignments, and check for any lateral bending or twisting. This type of damage may be due to overloads, corrosion, traffic impact, or support settlement.

- Examine all members and bearings for corrosion and loss of cross-sectional area. Particular attention should be given to areas below expansion joints and to details that trap water. The inspector should remove as much rust as possible, using a chipping hammer or paint scraper, and record the section loss. Some corrosion is so severe that holes are created through the steel plate. This should be recorded as through thickness section loss. If any section loss over 10 percent on a primary member is found, the District Engineer or the Inspection Consultant should be notified and the bridge should be re-rated for load.
- Look for pack rust, noted by individual plate bending between fasteners. The amount of plate separation caused by pack rust should be measured and recorded. Note any deformation of plates.
- Document all cracks. The District Engineer or the Inspection Consultant should be notified of newly discovered cracks in primary steel members. Include dates of when the crack was discovered, confirmed, or re-examined; its location, length, and width; and the location of crack tips. This information should be written directly on the cracked member with a permanent marker or a paint stick on weathering or corroded steel for easy reference and relocation at later dates. Sketches and/or photographs should be used to indicate the location, orientation, and length. Record the dimensions and details of the member containing the crack, any opening or closing of the crack as vehicles pass, corrosion conditions at the crack, and whether or not dirt or debris is found on the cracked steel surfaces.
- Check rivet/bolt heads on built-up components. Corrosion on the heads may indicate corrosion along the entire fastener length, reducing structural integrity.
- Check all fasteners. Signs of fatigue include rust bleeding/powder under the fastener head or nut, gaps between the connected parts and the fastener head or nut, a dull sound when the head is tapped with a hammer, and missing fasteners.
- Closely examine eyebar heads for cracks, corrosion, and lack of movement. Check any forged areas on eyebars for cracks or separations.
- Check to make sure all eyebars in a multiple eyebar member are parallel to one another.
- Check for bowed or buckled tension members. Unintended bending and compressive stresses may be introduced into a tension member from substructure settlement or heavily rusted/frozen pinned joints. Look for overloads on other members when this situation is encountered, since loads previously carried by the tension member must be redistributed somewhere else within the bridge.
- Document the primary truss gusset plates where limited access prevents section loss from being adequately quantified.

- Look for compression overload damage in the form of local member buckling or waviness. Global buckling will take the form of a bowed member or a member bowed into an “S” shape if support is provided between its ends.
- Check all pins for excessive wear.
- Check to see if pin spacers are keeping the eyebars or loop rods properly aligned and symmetric about the truss plane.
- Examine the condition of threaded members such as truss rods at turnbuckles.
- Check for heavily corroded pins that may have locked-up eyebar or loop rod movement. Transverse cracks may appear in the member body away from the forge zone or in the eyebar head.
- Look for signs of impact damage, including scrapes on member undersides, distorted members, and nicks or gouges on member edges or corners. Particularly strong collisions may tear the steel. Cracks can develop in the connections at each end of any member that has been hit.
- Inspect pins or pin-and-hanger assemblies in accordance with Part 4, 4.2.7.1.
- Inspect cables and rods in accordance with Part 4, 4.2.7.2.

Subsection 4.2.3 Steel Arch Bridges

Arches resist axial compressive loads and bending moments. Because they are not tension members, arches are not considered fracture critical even though most steel arches have only two main members. Tied arches are the exception and are considered fracture critical. Arch members are classified as solid-ribbed, braced-ribbed (trussed arch), spandrel-braced, or tied. The *Bridge Inspector’s Reference Manual* (BIRM*)* has several photographs in Chapter 8 illustrating some of these arch styles.

Solid-ribbed steel arches are fabricated into I-girders or box shapes. Braced-rib arches have two curves (usually fabricated boxes) defining the arch shape, braced with truss webbing between the curves. These are usually used for longer spans or where better control of live load deflections is required. Spandrel-braced arches are similar to solid-ribbed arches, but have diagonal bracing between the spandrel bents above the arch. Tied arches have their ends connected with a tension tie girder as a means to remove the arch’s horizontal thrust from its bearing. These tension ties are fracture critical components of the arch superstructure. The ties and arches are usually fabricated box members.

Arch ribs carry compressive loads and bending moments. Compressive forces are fairly constant throughout the arch. Bending moments will be variable and depend on the location of arch hinges. Moments are zero at the hinges. Arches may have three hinges (one at the crown and two at the bases), two hinges (at the bases), or no hinges (fixed). Columns or shafts on arch bridges may carry a combination of compressive loads and bending moments (spandrel columns), tensile loads (hangers or longitudinal bracing members), or compressive loads (longitudinal bracing). Hangers, arch braces, and spandrel braces are tension members.

- **Steel Deck Arch Bridges:** Steel deck arch bridges are structures with the deck placed on top of two or more riveted, bolted, or welded arches. The arches are the main load-carrying members and their ends bear on foundations at grade. Their bearing ends are usually pinned. The end reactions have a vertical component due to the dead and live gravity loads and a horizontal component due to the arch's outward thrust. A pin may also be present at the arch crown, forming a three-hinged arch. The area between the deck and arch is known as the spandrel. Deck arches use vertical compression members, called spandrel columns, to deliver the deck loads to the arch ribs. The spandrel columns may be rolled or built-up shapes. Each arch rib may be fabricated into an "I" or box shape (solid-ribbed arch) or into a truss shape (braced-rib arch). When diagonal braces connect the spandrel columns above the rib, the bridge is classified as a spandrel-braced arch. The floor system will contain floor beams, spandrel girders, and sometimes stringers. Secondary members include the upper and lower lateral bracing which brace the floor system and arch ribs, respectively. Transverse sway bracing keeps the ribs and spandrels in line laterally. Although many deck arch bridges have only two arch ribs, the bridges are not considered fracture critical since arches resist a combination of compression loads and bending moments, not tension. Open spandrel deck arch bridges are considered complex in Indiana.

Figure 4:4-16: Steel Deck Arch Bridge With Spandrel Bent Columns

- **Steel Through Arch Bridges:** Steel through arch bridges are structures with the deck placed below the crown of, and between, two riveted, bolted, or welded arches. As with deck arches, the arches are the main load-carrying members and are usually pinned, with the ends bearing on foundations at grade. A pin may also be present at the arch crown to form a three-hinged arch. Through arches use vertical tension members to suspend the deck under the arch ribs. The tension members may be steel cables, wire rope, or solid steel hangers. Each arch rib may be fabricated into a box shape (solid-ribbed arch) or more commonly into a truss shape (braced-rib arch). The floor system will contain floor beams, girders, and sometimes stringers. Secondary members include lateral bracing for the arch ribs and floor system, and transverse sway bracing to keep the ribs in line laterally. As with deck arches, most through arches are not fracture critical bridges.

Figure 4:4-17: Through Arch Bridge

- **Steel Tied Arch Bridges:** Steel tied arch bridges are special types of through arches. The ends of tied arches bear on piers and are tied together with a tie girder. The tie girder is in tension to resist the large horizontal thrusts of the arch rib. It functions in a similar manner to the string on an archer's bow. Because tied arch bridges have only two arches and two tie girders, tied arch bridges are considered fracture critical since a failure of one tie girder will directly lead to a failure of its associated arch. The tie girder may also behave as a bending member, in conjunction with the ribs, to deliver dead and live gravity loads to the pier. Primary and secondary members of tied arches are similar to those of through arches, although the arch ribs are typically solid box-shaped members. Floor beams frame directly into the webs of the tie girders, and cables or hangers (solid or hollow) directly support the tie girder. The hangers may be oriented vertically or diagonally.

Figure 4:4-18: Steel Tied Arch Bridge

The inspection of steel arch bridges should include the following items:

- View down the member's length to check vertical and horizontal alignments, as well as for any canting (lateral bending or twisting). This type of damage may be due to overloads, corrosion, traffic impact, or support settlement.
- Examine all members and bearings for corrosion and loss of cross-sectional area. Particular attention should be given to areas under deck joints and details that trap water. The inspector should remove as much rust as possible, using a chipping hammer or paint scraper, and record the section loss. Some corrosion is so severe that holes are created through the steel plate. This should be recorded as through thickness section loss. If any section loss over 10 percent on a primary member is found, the District Engineer or the Inspection Consultant should be notified and the bridge should be re-rated for load.
- Look for pack rust, noted by individual plate bending between fasteners. The amount of plate separation caused by pack rust should be measured and recorded. Note and measure any deformation of plates.

Figure 4:4-19: Pack Rust at Riveted Steel Arch Flange Plates

- Document all cracks. The District Engineer or the Inspection Consultant should be notified of newly discovered cracks in primary steel members. Include dates of when the crack was discovered, confirmed, and re-examined; its location, length, and width; and the location of crack tips. This information should be written directly on the cracked member with a permanent marker or a paint stick on weathering or corroded steel for easy reference and relocation at later dates. Sketches and photographs should be used to indicate the location, orientation, and length. Record the dimensions and details of the member containing the crack, any opening or closing of the crack as vehicles pass, corrosion conditions at the crack, and whether or not dirt or debris is found on the cracked steel surfaces.
- Check rivet/bolt heads on built-up components. Corrosion on the heads may indicate corrosion along the entire fastener length, reducing structural integrity.
- Check all fasteners. Signs of fatigue include rust bleeding/powder under the fastener head or nut, gaps between the connected parts and the fastener head or nut, a dull sound when the head is tapped with a hammer, and missing fasteners.
- Look for local compression overload damage in the form of local member component buckling, plate waviness, or crippling.
- Look for global buckling which will take the form of longitudinal rib misalignment.
- Inspect the longitudinal bracing members of braced rib arches. These members should be inspected in a manner similar to truss members (see Subsection 4.2.2). They are designed to take compressive loads, tensile loads, or both.
- Examine the rib splice plates for loose fasteners and excessive corrosion.

- Look for signs of impact damage, including scrapes on member undersides, distorted members, and nicks or gouges on plate edges or member corners. Particularly strong collisions may tear the steel.
- Inspect the hinge pins for corrosion and excessive wear.
- Inspect pins or pin-and-hanger assemblies in accordance with Part 4, 4.2.7.1.
- Inspect cables and rods in accordance with Part 4, 4.2.7.2.

Subsection 4.2.4 Steel Rigid Frame Bridges

Steel rigid frame bridges are structures in which the structure's inclined supporting "legs" are integrated with the girders to form a rigid frame. Rigid frames are usually constructed using welded plate girders and legs to form a "K" shape or triangular delta shape. Though the legs are used as bridge piers, the legs are actually part of the superstructure because of their rigid connection to the girders. This rigid intersection of the leg and girder is referred to as the knee and allows both the girders and legs to resist bending moments. Large moments and shear forces are resisted by the knee, resulting in a complex arrangement of stiffeners in this area. The legs are pinned at grade, and the girder ends supported by conventional abutments. Rigid frame bridges may use two or more frames to support the deck. The girders, legs, and bearings are all primary members on multi-rigid frame bridges. The diaphragms, cross-frames, longitudinal stiffeners, transverse stiffeners, and radial stiffeners are all secondary members. On two-frame bridges, the girders, legs, stringers, floor beams, and bearings are all primary members. Secondary members include the lateral bracing, longitudinal stiffeners, transverse stiffeners, and radial stiffeners. Spans of 50 to 200 feet are attainable using rigid frames.

Two-frame bridges are considered fracture critical. The curvature of the deck should be checked periodically to monitor for flattening and to check for sag. Check for uplift of the ends of short-end spans when the center span is loaded.

Figure 4:4-20: Steel Rigid Frame Bridge

The inspection of steel rigid frame bridges should include the following:

- View down the member’s length to check vertical and horizontal alignments, as well as for any lateral bending or twisting. This type of damage may be due to overloads, corrosion, traffic impact, or support settlement.
- Periodically survey the curvature of the deck to monitor flattening.
- Examine all members and bearings for corrosion and loss of cross-sectional area. Particular attention should be given to areas under the deck expansion joints and to details that trap water. The inspector should remove as much rust as possible, using a chipping hammer or paint scraper, and record the section loss. Some corrosion is so severe that holes are created through the steel plate. This should be recorded as through thickness section loss. If any section loss over 10 percent on a primary member is found, the District Engineer or the Inspection Consultant should be notified and the bridge should be re-rated for load.
- Look for pack rust, noted by individual plate bending between fasteners. The amount of plate separation caused by pack rust should be measured and recorded. Note and measure any deformation of plates.
- Document all cracks. The District Engineer or the Inspection Consultant should be notified of newly discovered cracks in primary steel members. Include dates of when the crack was discovered, confirmed, and re-examined; its location, length, and width; and the location of crack tips. This information should be written directly on the cracked member with a permanent marker or a paint stick on weathering or corroded steel for easy reference and relocation at later dates. Sketches and photographs should be used to indicate the location, orientation, and length. Record the dimensions and details of the member containing the crack, any opening or closing of the crack as vehicles pass, corrosion conditions at the crack, and whether or not dirt or debris is found on the cracked steel surfaces.
- Check rivet/bolt heads on built-up components. Corrosion on the heads may indicate corrosion along the entire fastener length, reducing structural integrity.
- Check all fasteners. Signs of fatigue include rust bleeding/powder under the fastener head or nut, gaps between the connected parts and the fastener head or nut, a dull sound when the head is tapped with a hammer, and missing fasteners.
- Look for overload damage in the form of compression flange buckling and tension flange elongation or fracture.
- Look for web crippling, a permanent wrinkling or buckling of the web due to overloads.

- Look for signs of impact damage, including scrapes on member undersides, distorted members, and nicks or gouges on plate edges or member corners. Particularly strong collisions may tear the steel.
- Inspect pins or pin-and-hanger assemblies in accordance with Part 4, 4.2.7.1.
- Inspect cables and rods in accordance with Part 4, 4.2.7.2.
- Look for uplift of the girders at the abutments and for misaligned bearings due to uplift.

Subsection 4.2.5 Steel Cable-Stayed and Suspension Bridges

- **Steel Cable-Stayed Bridges:** Steel cable-stayed bridges are typically long span structures that use one or two planes of inclined stay cables as their main means of support. The stay's opposite ends are attached to, or carried over, pylons, which deliver the cable forces to the foundation. The cables are tension members. Cable-stayed bridges are always considered complex bridges in Indiana and may be fracture critical.
- **Basket Handle, Cable-Stayed Arch Bridges:** Indiana has one basket handle, cable-stayed steel arch bridge carrying I-65 over State Route 46. On a basket handle cable-stayed bridge, the arches supporting the cable are connected at the top.

Figure 4:4-21: Basket Handle, Cable-Stayed Arch Bridge

Figure 4:4-22: Cable-Stayed Bridge

- **Suspension Bridges:** Suspension bridges are typically long span structures that support the deck from vertical cable hangers attached to two or more catenary main suspension cables. The main suspension cables are draped over towers and their ends are fixed to gravity anchors. Suspension bridges are always fracture critical and are considered complex bridges in Indiana.

Figure 4:4-23: Steel Pedestrian Suspension Bridge

As complex bridges, steel cable-stayed and suspension bridges will have their own operation and maintenance manuals to guide the inspector during routine evaluations. The reader is referred to the Federal Highway Administration (FHWA) publication HI-94-033, *Safety Inspection of In-Service Bridges Participant Notebook, Volume 3* for additional guidance.

Subsection 4.2.6 Moveable Steel Bridges

Movable steel bridges are discussed in detail in Part 5 of this manual.

Subsection 4.2.7 Inspection of Special Details in Steel Superstructures

4.2.7.1 Pins or Pin-and-Hanger Assemblies

Pins and pin-and-hanger assemblies are primary load-carrying connection assemblies found in many steel superstructures. Individual bridge pins are located on multi-span girders where it is necessary to locate a non-expansion hinge away from a pier. Pin-and-hanger assemblies, consisting of two pins and two hangers, are found on multi-span girder bridges where it is necessary to locate the expansion hinge away from a pier. The assemblies are placed at the tip of a girder's cantilever span and are used to suspend an adjacent span. Cantilevered trusses also use pin-and-hanger assemblies. On two-girder system bridges, pin-and-hanger assemblies are fracture critical members. All bridges with pin-and-hanger details and all trusses with pin and eyebar details are considered complex bridges in Indiana.

Hangers are designed to act as links and are consequently intended to be tension-only members. At least two are used per connection, one on each side of the girder web. Hangers may be shaped as simple flat plates or as eyebars.

Hanger plates are susceptible to damage when corrosion freezes the pins and prevents free rotation. When this occurs the assembly ceases to behave as a hinge and begins to carry bending moments. These moments introduce bending stresses in the hangers in addition to the tensile stress for which the hangers were designed. Torsional forces in the pin can cause cracks and pin failure. Out-of-plane bending stresses may also be generated from girder misalignment or pack rust. As a result, overstress cracks may develop in the hanger plate(s).

On trusses, pins are normally employed to connect the ends of eyebars or loop rods, although large pins can connect the ends of modern built-up members. On girders, pins pass through web plates to form a non-expansion hinge. Pins are intended to be frictionless connections that allow for member rotation, but are not designed to carry any torsion. They are fabricated in a variety of sizes. The smallest are solid and use cotter pins to prevent the pin from walking out of the connection under vibratory loads. Medium diameter pins are also solid, but their ends are threaded so that self-locking nuts can be used to prevent the pin from walking out. Sometimes holes are drilled through the center axis of medium-sized pins. The largest pins have holes drilled through their center axis, through which passes a threaded rod. The rods also pass through pin end cap plates. Nuts are threaded onto the rod to retain the cap plates and the pin.

The inspection of pins and pin-and-hanger assemblies should include the following items:

- Carefully check all edges and surfaces of all hangers, especially the ends beyond the pin centerlines, and the forged areas of any eyebars for cracks or corrosion. Forged areas will usually be near the eyebar head and body junction.
- Check both sides of the hanger for cracks, if possible. A flashlight and inspection mirror can help.
- Use NDT methods (dye penetrant, magnetic particle, ultrasonic, etc.) to look for cracks. NDT should be performed as part of an In-Depth Inspection.
- Immediately report any cracks or section loss greater than 10 percent to the District Engineer or the Inspection Consultant. The nature of pin-and-hanger assemblies is such that a failure of one assembly may cause a domino effect failure on multi-girder bridges.

Figure 4:4-24: Crack in Hinge Girder

Figure 4:4-25: Pin-and-Hanger Assembly

- Tap the pin or threaded rod nut with a hammer to check for looseness. If the pins are excessively loose, notify the District Engineer or the Inspection Consultant immediately. A bridge inspector should never unscrew a pin nut or remove a cap plate to get a better look at the pin. Disassembly is not part of a Routine Inspection. Doing so could be catastrophic if pack rust between the girder web and hanger has placed the assembly on the verge of failure. Disassembly is only undertaken as part of an In-Depth Inspection program and only after proper auxiliary joint support is in place.

Figure 4:4-26: Single Pin and Plate Assembly

- Examine all pins for signs of the desired member rotation about the pin, such as powdery orange or red rust (fretting rust) near surfaces that rub or bear, cracked paint between the pin and member, or physical movement as traffic crosses the bridge.

- Measure the amount of pin wear on truss or girder hanger expansion hinge assemblies. Since access may be difficult due to closely spaced members or cap plates, creative measurements must be made. Two measurements must be taken at each pin to obtain adequate information of pin or member wear. Measure the distance from the centerline of the pin to the end of the hanger, (shown as Dimension 1 in Figure 4:4-27) and measure from the center of the pin to the inside flange surface of the girder through which the pin passes (shown as Dimension 2 in Figure 4:4-27). These readings will give measurements for wear at the pin/hanger interface and pin/web interface, respectively. Make these measurements from the centerline of the threaded rod on pins using cap plates.
- Measure the amount of pin wear on non-expansion hinges. Measure from the center of the pin to the inside surface of the girder's top and bottom flanges. These readings will give measurements for wear at the bottom of pin/web interfaces and top of pin/web interfaces, respectively (shown as Dimensions 3 and 4 in Figure 4:4-27). Make these measurements from the centerline of the threaded rod on pins using cap plates.
- Compare these measurements to the distances shown on the original design drawings, accounting for the pinhole tolerance (usually 1/32 inch). Wear of 1/8 inch or greater should be brought to the attention of the District Engineer or the Inspection Consultant. If the original design drawings are not available, record the measurement for comparison to measurements taken on future inspections. If possible, a wire or stiff steel rule should be used to probe between the plies of plates to measure the distance from the pin surface to the surfaces described above.
- Look for fretting corrosion between the hanger and girder web, which will be evident by dusty-looking reddish rust around the plates' interface. Fretting corrosion is caused by two tightly fitting plates rubbing against each other.
- Check for ratcheting. On new structures, rotations are accommodated by the girder web sliding on the pin surface. Fretting corrosion between the web hole and pin surface will advance, eventually "locking up" the web/pin movement. After this occurs, rotations take place by the hanger sliding on the pin surface. This is known as ratcheting, and is evidenced by a broken paint film, wear marks, and corrosion between the pin nut and hanger plate.

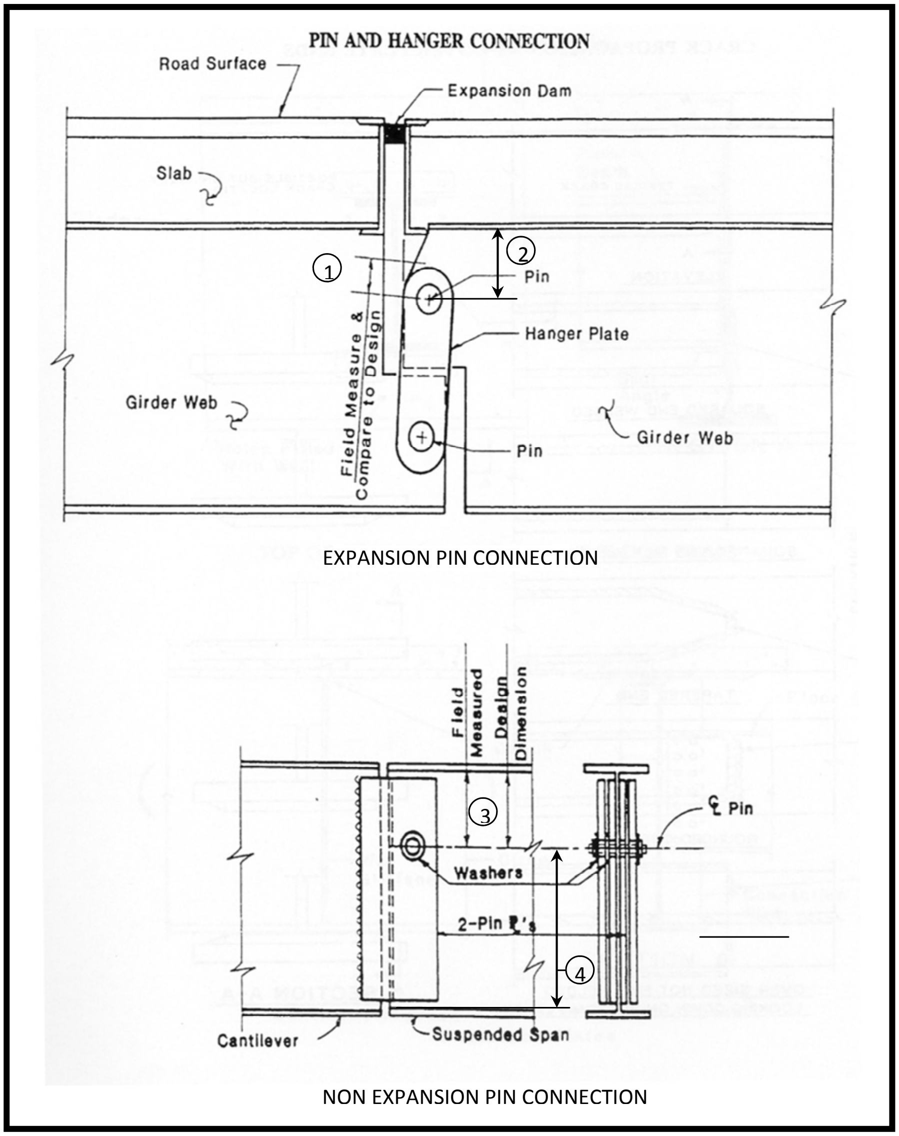


Figure 4:4-27: Pin Connection Measurements

- Look for pack rust between the girder web and hanger. Pins connecting plate hangers or tightly packed eyebars are difficult to access and often do not receive proper cleaning or painting during maintenance operations. Excessive corrosion may lock up the joint, introducing unintended bending stresses into the pin-and-hanger or superstructure member. Note any deformation of plates.
- Check the cap plates for flatness.
- Check to make sure adjacent girder flanges and webs are in alignment.
- Measure the distance between the hanger and girder web at several locations. A variation of 1/8 inch or more could mean hanger twist or lateral movement.

- Bridges with pin-and-hanger type connections should be clearly identified in the Central Database. Currently, the Indiana Department of Transportation (INDOT) hires a consultant to inspect and perform NDT on all pin-and-hanger connections on all state- and county-owned bridges that carry vehicular traffic on a five-year cycle. The Indiana Toll Road hires a separate consultant to perform the same level of inspection for bridges under its jurisdiction on a four-year cycle.

Figure 4:4-28: Pin Shear Failure

4.2.7.2 Cables and Rods

Cables and rods are tension-only members used in suspension, cable-stayed, post-tensioned concrete, tied arch, and some timber bridges.

Cables may be used as vertical suspenders, angled cable stays, catenaries, or post-tensioning strands. Unlike solid rods, many individual wires are helically spun together and placed parallel to each other, or spun into rope to build up the size of the cable. End anchorages are usually made by brooming or spreading apart the cable wires inside a steel fitting. The conical-shaped steel fitting is then filled with a socketing medium, such as molten zinc, to lock the wires in place. For smaller diameter cables or individual strands, jaws (wedges) can be placed around the strand to provide anchorage. These jaws grip and anchor the strand as the strand is pulled and seated into a conical-shaped anchor block.

Rods are most often used to longitudinally post-tension concrete box girders and to transversely post-tension timber slab bridges. Normally, only the ends of the rods are visible for inspection, although early examples of post-tensioned concrete box girders left the entire rod exposed within the cells.

Corrosion is the primary enemy to any steel cable or rod. Note that corrosion has a more profound structural effect on cables than it does on solid members. Because cables have a much greater surface area than a solid rod with the same cross-sectional area, surface corrosion on the wires will reduce a cable's cross-sectional area more than on a similarly sized solid member.

Inspection of rods and cables should include the following:

- Look for broken wires. Broken wires may be caused by fatigue due to bending near the anchorages and excessive section loss due to corrosion or abrasion against the cable guide.
- Look for corrosion and document its extent. Severe corrosion may also form pack rust between individual wires or between the wires and end fittings.
- Inspect the end fittings, especially lower end fittings, where water would tend to accumulate. Check for any cracks in the end casting.
- Note if any rods or cables are vibrating excessively due to wind or traffic loads and note the amplitude, the wind speed, and the wind direction.
- Check for cable loosening or slippage at the end fittings. Signs of this condition may be wire abrasion and/or corrosion.
- Note any slipping or unraveling of the main cable banding on suspension bridges.

Figure 4:4-29: Cable Anchorage for a Cable-Stayed Bridge

Figure 4:4-30: Cable Anchorage for a Tied Arch Bridge

SECTION 4.3 CONCRETE SUPERSTRUCTURES

Concrete has been used to construct bridges in the United States since 1889. With the exception of arches, conventional reinforced concrete was initially limited to use for short, single-span bridges. The development of prestressed concrete in the middle part of the 1900s, with the subsequent development of post-tensioned concrete boxes, allowed concrete to gain acceptance for use on medium- and long-span bridges. Concrete superstructures can be configured in many different ways, including slab bridges, reinforced girder bridges, concrete arch bridges, and box beam bridges.

Subsection 4.3.1 Cast-in-Place Slab Bridges

Cast-in-place slab bridges are the simplest type of concrete bridge. The slab acts as a single, wide beam spanning from substructure unit to substructure unit. There are no individual beams with this type of bridge, and the slab also acts as the deck. Slabs are used for simple spans up to approximately 45 feet. Continuous slab bridges can be built with slightly longer span lengths. To attain greater negative bending strength on continuous bridges, the slab may be thickened (haunched) over the piers. The main reinforcing steel is placed parallel to traffic and located near the bottom of the slab in positive bending regions, and towards the top of the slab in negative bending regions. On older and more complex structures, continuous cast-in-place slabs may contain voids to lighten the dead load of the bridge.

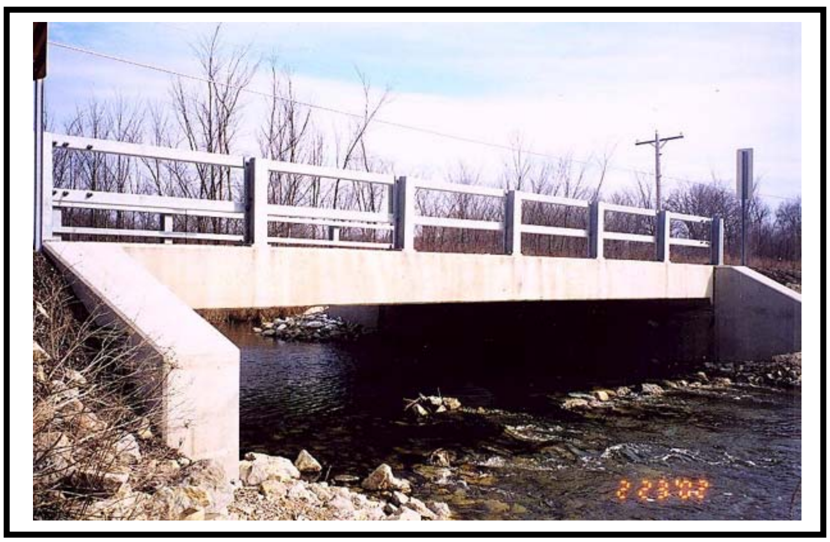


Figure 4:4-31: Single Span, Reinforced Concrete Slab Bridge

Inspection of a concrete slab superstructure should include the following:

- Check for cracks and note their location, orientation, length, maximum width, and type. Cracks to note include:
  - Transverse flexural cracks on the top side of the slab adjacent to, and over, piers and where reinforcement bars end. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks on a primary concrete member wider than 1/8 inch.
  - Diagonal or transverse temperature/shrinkage cracks. These will be found on most concrete decks and can provide a means for chlorides to reach steel reinforcement.
  - Diagonal shear cracks on the copings over or near the bearing areas at piers/abutments.
- Check for pop-outs, scaling, abrasion, and rutting. This may be most evident in the gutters and around the drains.
- Look for spalls and note any large individual spalls.
- Look for signs of corroding reinforcing steel, such as rust stains.
- Check the entire member for signs of corroding reinforcing steel, as indicated by rust stains, spalling, or exposed reinforcement.
- Look for efflorescence. Note if it is stained with rust since this condition suggests reinforcing steel corrosion. These defects can grow into larger problems such as delaminations and spalls.
- Check for areas of delaminations. Loose concrete can fall and cause serious damage or injury.
- Check for excessive dead load deflection.
- Note the condition of repaired areas.
- Check for water leakage. Water leakage frequently appears on support structures, under drains, or under expansion joints.
- Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.
- Look for collision damage, including scrapes on member undersides, chips, cracks, spalls, or a missing section of a member. Strong collisions may expose several reinforcing bars.
- Check for missing tie rods, bolts, or nuts.

Subsection 4.3.2: Reinforced Concrete Girder Bridges

Reinforced concrete girder bridges (sometimes called Tee Beam bridges in other states) were commonly constructed in the early half of the 20th century. They are cast-in-place structures, with the deck cast monolithic with the beams. The “T” shape is created by the rectangular beam stem below the deck, with the deck forming the top flange. Because the deck acts as the top flange, deterioration will affect the superstructure rating. The fascia beams on some reinforced concrete girder bridges are upturned, doubling as parapets. Reinforced concrete girder bridges are most commonly used for simple spans, although they may be made continuous by haunching the beam stems over the piers. Individual spans may reach 50 feet in length, with the beams spaced from about three to eight feet. Common beam depths range from 18 to 24 inches. The main reinforcing steel is placed longitudinally near the bottom of the beam in positive-bending regions and longitudinally within the deck in negative-bending regions. Vertical stirrups placed along the beams serve as shear reinforcing.

Figure 4:4-32: Reinforced Concrete Girder Bridge

Figure 4:4-33: Reinforced Concrete Girders

Figure 4:4-34: Reinforced Concrete Girder Bridge With Buttressed Fascia Girders

Figure 4:4-35: Leaching at Mudwall on Reinforced Concrete Girder Bridge

The inspection of a reinforced concrete girder bridge superstructure should include the following:

- Inspect each girder for cracks, noting the location, orientation, length, maximum width, and type of each. Look for transverse flexural cracks on the underside of the beams between supports and on top of the deck over the piers on continuously supported bridges. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks on a primary concrete member wider than 1/8 inch.

- Check for deteriorated concrete in the flexural zones that is causing debonding of the reinforcing steel. This is critical near the ends of the reinforcing steel bars since a certain length of the bar must be embedded within sound concrete to fully develop its strength. Delaminations, spalls, and longitudinal cracks can all cause debonding.
- Examine the support areas for shear cracks. Shear cracks will be diagonal, extending up from the bearing towards mid-span. Wide shear cracks suggest the loss of aggregate interlock, meaning the member may be supported by the reinforcing stirrups.
- Check the entire member for signs of corroding reinforcing steel, as indicated by rust stains, spalling, delaminations, or exposed reinforcement.
- Look for efflorescence. Note if it is stained with rust since this condition suggests reinforcing steel corrosion. These defects can grow into larger problems such as delaminations and spalls.
- Investigate the bearing areas for spalled concrete due to friction from thermal movement or crushed concrete due to bearing pressure overloads.
- Check the member under drains or leaking expansion joints for cracks, delaminations, spalls, and exposed reinforcing steel.
- Check previously repaired areas for soundness by hammer tapping.
- Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.
- Look for collision damage, including scrapes on member undersides, chips, cracks, spalls, or a missing section of a member. Strong collisions will expose several reinforcing bars.

Subsection 4.3.3 Concrete Through Girder Bridges

Concrete through girder bridges were constructed in the early half of the 20th century. They are cast-in-place structures, with the deck cast monolithic with the girders. Two deep girders are normally used and also serve as the bridge parapets. Through girder bridges are used for short simple spans. The deck is connected to the lower portion of the girders. Because the deck must span between the girders, through girder bridge widths rarely exceed 24 feet. The girders themselves are fairly large, usually 18 to 30 inches wide, and four to six feet deep. The main reinforcing steel is placed longitudinally near the bottom of the girders, while the main deck reinforcing steel is placed transversely in the deck bottom. Vertical stirrups placed along the girders serve as shear reinforcing.

The inspection of a reinforced concrete through girder bridge should include the following:

- Inspect each girder for cracks, noting the location, orientation, length, maximum width, and type of each.
- Look for transverse flexural cracks on the underside of the girder between supports. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks wider than 1/8 inch on a primary concrete member.
- Look for longitudinal cracks at the interface of the web and top flange that are not substantially closed as this may indicate permanent deformation of the stirrups.
- Check for deteriorated concrete in the flexural zones that is causing debonding of the reinforcing steel. This is especially critical near the ends of the reinforcing steel bars since a certain length of the bar must be embedded within sound concrete to fully develop its strength. The deterioration causing the debonding may be delaminations, spalls, or longitudinal cracks.
- Examine the support areas for shear cracks. Shear cracks will be diagonal, extending up from the bearing towards mid-span. Wide shear cracks suggest the loss of aggregate interlock, meaning the member could by supported by the reinforcing stirrups.
- Check the entire member for signs of corroding reinforcing steel, as indicated by rust stains, spalling, or exposed reinforcement.
- Look for efflorescence. Note if it is stained with rust since this condition suggests reinforcing steel corrosion. These defects can grow into larger problems such as delaminations and spalls.
- Investigate the bearing areas for spalled concrete due to friction from thermal movement, or crushed concrete due to bearing pressure overloads.
- Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.
- Check the member under drains or leaking expansion joints for cracks, delaminations, spalls, and exposed reinforcing steel.
- Check previously repaired areas for soundness by hammer tapping.
- Look for collision damage, including scrapes on member undersides, chips, cracks, spalls, or a missing section of a member. Strong collisions may expose several reinforcing bars.

Figure 4:4-36: Reinforced Concrete Through Girder Bridge

Subsection 4.3.4 Precast Concrete Channel Beam Bridges

Channel beam bridges use precast channel beams as the primary load-carrying members. Channel beam bridges can be designed using standard reinforcing steel or as prestressed members, although most channel beam bridges in Indiana were constructed using standard reinforcing steel. The channels are placed on the substructure units so that they form an upside down "U," with the vertical legs forming the beams and the horizontal top slab forming the deck. The channels are placed tightly side-by-side and should be transversely connected by tie rods or bolts so that the beams act as a unit under live loads. Grouted shear keys also help the beams to act together. Channel beam bridges are used for simple spans up to about 50 feet. Widths of the individual beams usually range from three to four feet. The main reinforcing steel is placed longitudinally near the bottom of the channel legs, while the main deck reinforcing steel is placed transversely in the top slab. Generally, this reinforcing is hooked at the end, but sometimes straight bars were used. Inspectors should note any evidence of hooks. Vertical stirrups may be placed along the channel legs to serve as shear reinforcing.

Figure 4:4-37: Deteriorated Prestressed Concrete Channel Beams

Inspection of precast concrete channel beam bridges should include the following:

- Sight down each beam and check for excessive or differential deflections, or leaking and efflorescence between channel beams. This may indicate a beam is losing its prestressing force and is unable to carry the loads for which it was designed. This may also indicate failed shear keys. Once the shear keys have failed, live loads cannot be shared between adjacent beams.
- Inspect each beam for cracks, noting the location, orientation, length, maximum width, and type of each.
- Look for transverse flexural cracks on the beam underside in the positive moment regions. Their presence indicates a serious structural overload. Measure the crack widths and lengths and document their location. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks on a primary concrete member wider than 1/16 inch.
- Examine the beam ends for evidence of cracked or spalled concrete, sometimes accompanied by corroded reinforcing strands. This may occur due to leaking expansion joints that corrode the reinforcing steel.
- Look for diagonal shear cracks on the beam sides near the abutments and piers.
- Look for vertical cracks on the beam sides near the abutments and piers. Vertical cracks in these areas suggest the bearing assemblies are restricting beam movement.
- Examine the underside of each beam for parallel longitudinal cracks. These usually occur along the reinforcing and may occur due to corrosion or inadequate concrete cover. Rust stains that accompany the cracks suggest that the reinforcing is corroding and debonding.

- Check the beams, especially the fascias, for traffic impact damage. Severe impacts that expose several reinforcing bars or prestressing strands may justify replacement of the beam.
- Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.
- Verify that any drains are open.
- Document delaminations, spalls, and exposed reinforcing steel.
- Measure and record the diameter of exposed reinforcing.
- Check for missing tie rods, bolts, or nuts.

Subsection 4.3.5 Reinforced Concrete Arch Bridges

Reinforced concrete arch bridges are constructed in either open-spandrel or closed-spandrel configurations.

Open-spandrel arch bridges use either cast-in-place arch ribs, or a single arch ring as the primary load-carrying members. The arches resist a combination of axial compression and bending moments. The deck and floor system are placed above the arches, and spandrel columns and caps (bents) deliver these loads to the arch. The space between the deck and arch, called the spandrel, is left open. Since the arch acts primarily as a compression member, longitudinal steel is uniformly distributed around its perimeter, contained by transverse ties. The spandrel bent columns are reinforced in a similar manner. Spandrel bent caps act as fixed end beams, so reinforcing steel is placed near the bottom, between the columns, and near the top, above the columns. Vertical stirrups placed along the cap serve as shear reinforcing. The deck and floor system loading the spandrel arches are designed and reinforced similar to other reinforced concrete beams. Arch components are shown in Figure 4:4-38.

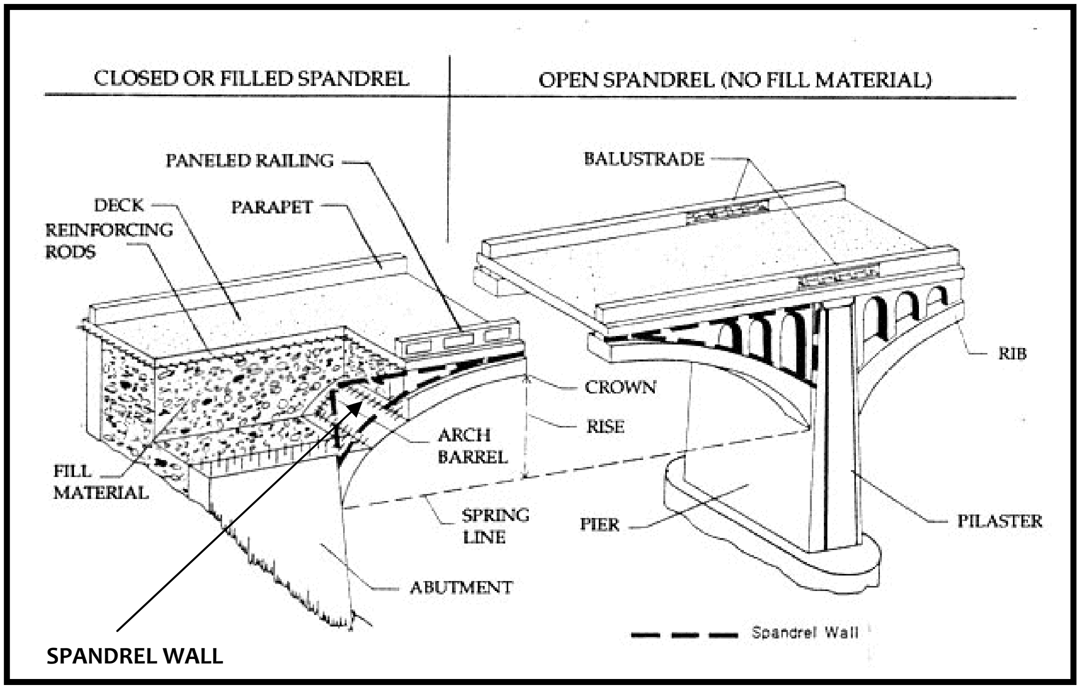


Figure 4:4-38: Concrete Arch Components

Figure 4:4-39: Open-Spandrel Reinforced Concrete Arch

Closed-spandrel arch bridges use a single, cast-in-place arch ring or barrel as the primary load-carrying member, with the arch resisting a combination of axial compression and bending moments. The spandrel area is enclosed by solid walls, usually built above the arch ring edges. Some spandrel walls are set outside of the arch ring and are tied to the arch ring with reinforcing bars. Over time, this reinforcing corrodes and the spandrel wall can be pushed out and away from the arch ring, accelerating deterioration and loss of fill. See Figure 4:4-40 below.

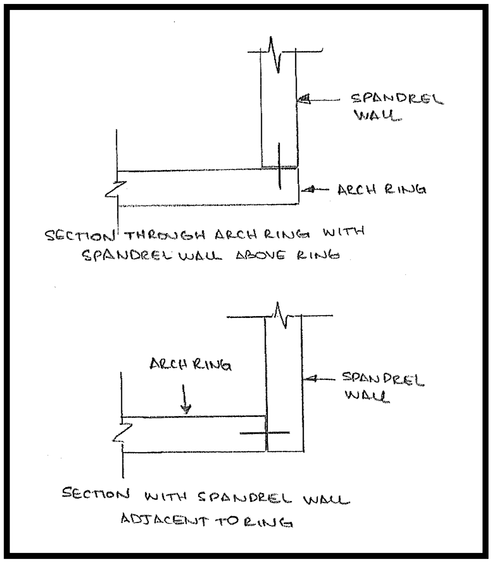


Figure 4:4-40: Closed Spandrel Wall Construction Details

Closed spandrel arches are considered underfill structures when the level of soil or fill is higher than the level of the copings or headwall/spandrel walls. Underfill structures are discussed in Part 4, Chapter 9.

The deck/roadway is always placed above the arches, and the spandrel area may be filled or vaulted (open). In filled spandrels, the roadway pavement bears on fill material that occupies the spandrel area. This fill is contained by solid spandrel walls built above the barrel edges. Main reinforcing steel for solid spandrel walls retaining fill is placed at the back or fill side of the wall and cannot be inspected. The fill makes it impossible to inspect the top of the arch. In vaulted (open) spandrels, the structural deck and floor system transfers loads to the arch by way of transverse spandrel walls or spandrel bents. In this configuration, the spandrel walls are nonstructural. The spandrel bents, deck, and floor system are reinforced similar to open spandrel arches. Arch barrels are reinforced with longitudinal steel distributed around the perimeter, contained by transverse ties. The top side of the barrel cannot be inspected, unless access is provided in vaulted, closed-spandrel arch bridges. Most arches have construction joints three to four feet in from the copings. These areas are subjected to cracks, delamination, spalls, leaching, and leakage.

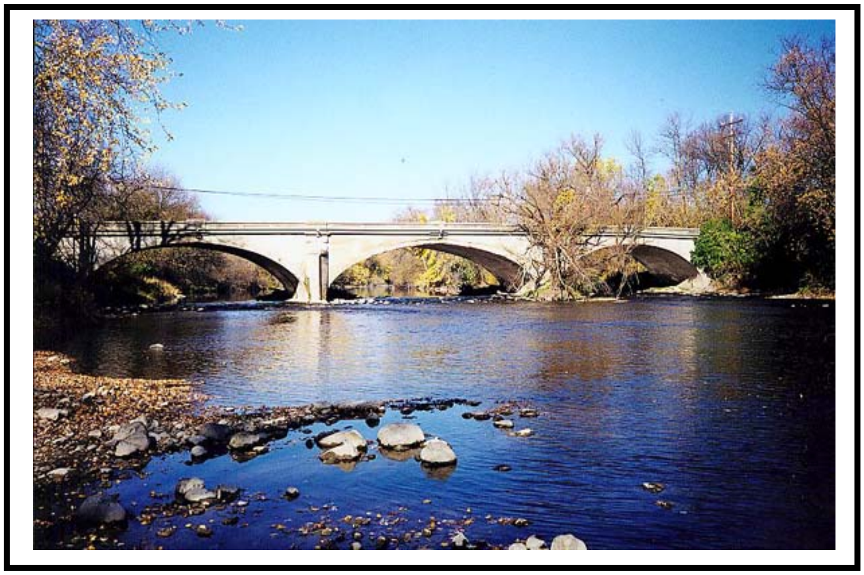


Figure 4:4-41: Multi-Span, Closed-Spandrel, Concrete Arch Bridge

Inspection of reinforced concrete arch bridges should include the following:

- Inspect all concrete for cracks, noting the location, orientation, length, maximum width, and type of each. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks on a primary concrete member wider than 1/8 inch.
- Examine the bearing areas for signs of concrete crushing, since the highest compressive forces experienced by an arch are found at the spring line. Crushing results in a loss of arch cross-sectional area, increasing the axial stresses.
- Look for longitudinal cracking along the arch axis. Longitudinal cracks indicate a possible structural overload or differential settlements.
- Check the entire arch and spandrel wall for delaminations, spalls, and exposed reinforcing steel. These defects reduce the member cross-sectional area, resulting in higher stresses.
- Check the entire arch for transverse cracks. These are the result of excessive bending moments or arch support settlements.
- Look for leaching and rust stains along the entire arch and spandrel wall.
- Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.
- Check areas exposed to drainage and roadway runoff. The runoff may cause scaling, spalling, and concrete contamination.
- Check to make sure weep holes in closed-spandrel arch structures are functioning.

- Check to make sure surface drains are functioning properly so that water does not penetrate the fill. This is especially important in closed-spandrel arch bridges.
- Examine previous repair areas for soundness by hammer tapping.
- Check the arch/spandrel column interface for transverse flexural cracks. These cracks may extend up several feet above the arch rib. They are an indication of excessive column bending due to overloads or differential arch deflection.
- Check the spandrel bent cap/spandrel column interface for horizontal or diagonal flexural cracks. These cracks will originate at the inside corner of the cap/column junction and are another sign of excessive bending due to overloads or differential arch deflection.
- Check the mid-height of the column for flexural cracks, as this is another sign of structural overloads or differential arch deflection.
- Examine the entire column for longitudinal cracks and crushed concrete. This indicates a serious structural overload.
- Check columns for delaminations, spalls, and exposed reinforcing steel. These defects reduce the member cross-sectional area, resulting in higher stresses.
- Check for traffic impact damage, including scrapes on member undersides, chips, cracks, spalls, or a missing section of a member.
- Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

Subsection 4.3.6 Prestressed Concrete Arch Bridges

Prestressed concrete arch bridges are not common in Indiana. Arches carry axial compressive stresses, as well as bending, tension, and compressive stresses. Normally, the axial loads are great enough on an arch that there are no net tensile stresses due to bending. When bending stresses are large enough to produce net tension, post-tensioning is used to pre-compress the arch cross section. This keeps the entire cross section in compression, eliminating any net tensile stress.

Figure 4:4-42: Open-Spandrel, Prestressed Arch Bridge

Inspection of prestressed arch bridges should include the following:

- Inspect all concrete for cracks, noting the location, orientation, length, maximum width, and type of each.
- Look for transverse flexure cracks along the arch. Their presence indicates a serious structural overload, loss of prestressing/post-tensioning force, or arch support settlements.
- Look for longitudinal cracks at the interface of the web and top flange that are not substantially closed below any surface damage. This indicates permanent deformation of the stirrups.
- Examine the bearing areas for signs of concrete crushing since the highest compressive forces experienced by an arch are found at the spring line. Crushing results in a loss of arch cross-sectional area, increasing the axial stresses.
- Look for longitudinal cracking along the arch axis. Longitudinal cracks indicate a structural overload.
- Check the entire arch for delaminations, spalls, and exposed reinforcing steel. These defects reduce the member cross-sectional area, resulting in higher stresses.
- Look for leaching and rust stains along the entire arch. These defects can grow into larger problems such as delaminations and spalls.
- Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

- Check for impact damage, including scrapes, chips, cracks, spalls, or missing concrete.
- Check areas exposed to drainage and roadway runoff. The runoff may cause scaling, spalling, and concrete contamination.
- Examine previous repair areas for soundness.

Subsection 4.3.7 Concrete Rigid Frame Bridges

Rigid frame bridges are structures in which the vertical or inclined supporting “legs” are cast monolithically with the girders or slab to form a rigid frame. These bridges are usually single-span structures constructed to form an inverted channel, usually of a slab design. Multiple span bridges may also be constructed by forming a rectangular shape, a “K” shape, or a triangular delta shape. Though the legs are used as bridge piers, the vertical or inclined legs are actually part of the superstructure because of their rigid connection to the horizontal slab or girders. This rigid intersection of the leg and horizontal member is referred to as the knee and allows both members to resist bending moments. Main reinforcing steel in the horizontal members is placed longitudinally near the bottom of the slab or girder between the abutments and legs. At the knees, it is placed longitudinally near the top on continuous bridges and around the outside or the corner on single-span bridges. Main reinforcing steel is placed vertically on both frame leg faces on continuous bridges and only on the traffic face of single-span bridges. Vertical stirrups placed along the horizontal member of beam frames serve as shear reinforcing, while transverse ties are placed along the legs. Spans of 50 to 200 feet are attainable using rigid frames. Figure 4:4-43 shows a concrete rigid frame bridge.

Figure 4:4-43: Concrete Rigid Frame Bridge

Inspection of rigid frame bridges should include the following items:

- Inspect all members for cracks, noting the location, orientation, length, maximum width, and type of each.
- Look for transverse flexural cracks in members carrying moments. Cracks over 1/8-inch wide in the flexural region may indicate a serious structural overload.
- Check for deteriorated concrete in the flexural zones that may be causing debonding of the reinforcing steel. This is especially critical near the ends of the reinforcing steel bars, since a certain length of the bar must be embedded within sound concrete to fully develop its strength. The deterioration causing the debonding may be delaminations, spalls, or longitudinal cracks.
- Check for shear cracks. Shear cracks will be diagonal, located near the end of a span, and inclined towards the center top. Shear cracks may also occur in the knee area angled down into the legs. Wide shear cracks suggest the loss of aggregate interlock, meaning the member could be supported by the reinforcing stirrups.
- Check the entire member for signs of corroding reinforcing steel, as indicated by rust stains or exposed reinforcement.
- Look for efflorescence, and note if it is stained with rust since this condition suggests reinforcing steel corrosion.
- Check the bearing areas for spalled concrete due to friction from thermal movement, or crushed concrete due to bearing pressure overloads.
- Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.
- Check members under drains or leaking expansion joints for cracks, delaminations, spalls, and exposed reinforcing steel.
- Check previously repaired areas for soundness by hammer tapping.
- Look for collision damage, including scrapes on member undersides, chips, cracks, spalls, or a missing section of a member. Strong collisions may expose several reinforcing bars.

Subsection 4.3.8 Precast Concrete Slab and Box Beam Bridges

In precast, concrete, voided slab bridges, each slab acts as a single, wide beam spanning from substructure unit to substructure unit. Precast slabs will generally have two or three elliptical or circular voids to reduce material weight, although solid slabs may be used for shorter spans. The precast slab may act as the superstructure and the deck. Precast voided slabs are manufactured in a plant and pre-tensioned. Each slab or plank is usually three or four feet wide, with depths ranging from about 15 to 26 inches. Slabs are placed tightly side-by-side and transversely clamped together so that the individual planks act as a unit under live loads. Grouted vertical shear keys also help the beams to act together. Precast voided slabs are used for spans up to 100 feet. The main steel prestressing strands are placed parallel to traffic and located near the bottom of the slab.

Prestressed box beam bridges are similar to precast voided slabs. However, precast box beams contain only a single void. In early applications, the top flange of the box beam acted as the deck. Asphalt overlays were also common. These were generally placed directly on the beams, but were sometimes placed over a membrane.

INDOT has not allowed asphalt overlays on box beam bridges on state routes since 1980, except for short-term repairs. Any box beam bridge with an asphalt overlay on a state route is considered as a temporary bridge and is coded as such in the National Bridge Inventory (NBI) database.

Sometimes a concrete deck is placed on top of box beams. These concrete decks often act compositely with the box beams.

Each beam is usually three or four feet wide, and 12 to 60 inches deep. The beams may be placed tightly side-by-side and transversely clamped together so that the individual beams act as a unit under live loads. Grouted shear keys also help the beams to act together. The beams may also be spaced two to six feet apart to form a bridge similar in appearance to a reinforced concrete girder bridge. In this configuration, a structural deck is constructed on top of the beams.

Figure 4:4-44: Precast, Prestressed, Concrete Deck Beams

Precast box beam bridges are used for simple spans up to 130 feet in length. The main steel prestressing strands are placed parallel to traffic and located in the bottom flange of the box. Conventional reinforcing steel ties are placed transversely along the beam for shear reinforcement.

Inspection of precast slab and box beam bridges should include the following:

- Sight down the length of the slabs or box beams to check for sagging. Sagging is a sign that the beam is losing its prestressing force and may be unable to carry the loads for which it was designed.
- Check for differential deflection between slabs or beams placed next to each other. This is a sign that the slabs or boxes are not acting as a unit and may be unable to carry the design loads. It may also indicate failed shear keys. Once these keys have failed, live loads cannot be shared between adjacent beams.
- Inspect each beam for cracks, noting the location, orientation, length, maximum width, and type of each.
- Examine the beam underside for parallel longitudinal cracks. These usually occur along the prestressing strands and may occur due to inadequate concrete cover. Rust stains that accompany the cracks suggest that the prestressing strands are corroding and debonding. Document any exposed strands.

- Document any prestressing strand corrosion. Visual evidence of prestressing strand corrosion includes rust staining, delaminations, and spalls exposing corroded reinforcement. NDT allows detection before visual signs are present. Refer to Part 6 for a discussion of relevant NDT techniques.
- Look for longitudinal cracks at the interface of the web and top flange of a box beam that are not substantially closed below any surface damage. This indicates permanent deformation of the stirrups.
- Look for transverse flexural cracks on the slab or box beam underside in the positive moment regions. Their presence indicates a serious structural overload or loss of prestressing/ post-tensioning force. Measure and document the crack widths and lengths and document their location.
- Look for diagonal shear cracks on the beam sides near the abutments and piers.
- Look for vertical cracks on the beam sides near the abutments and piers. Vertical cracks in these areas suggest the bearing assemblies are restricting beam movement.
- Document box beam top flange transverse flexural cracks and any leaching and rust staining that may accompany them. This will usually be performed during a Special Inspection, as the underside of a box beam's top flange can only be seen from inside the cell.

Figure 4:4-45: Longitudinal Cracking in Precast Box Beam

- Evaluate barrier and utility connections. These connections can act as entry points for water and chlorides, thereby creating a corrosive environment deep inside the beam.

- Check for any super elevation irregularities on curved box beam bridges. This is a sign that torsional distress has occurred.

- Examine the slab or beam ends for evidence of cracked or spalled concrete, sometimes accompanied by corroded reinforcing strands. This may occur due to leaking expansion joints that corrode the reinforcing or prestressing steel. It may also be the result of a lack of non-prestressed reinforcement in the zone of prestressing force transfer.

- Check the slabs and beams, especially the fascias, for traffic impact damage. Severe impacts that expose several prestressing strands may justify replacement of the beam.

- Check for leakage and efflorescence between the longitudinal joints of slabs or box beams placed next to each other. This condition, along with reflective longitudinal cracking on the deck surface, suggests that the grouted shear keys between the members have failed. Leakage may indicate an increased likelihood of prestressing strand corrosion.

- Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

- Verify that the drain holes are present and open. Recommend clearing clogged drain holes. Trapped water may cause strand corrosion and longitudinal cracking as the water freezes and thaws.

- Look for delaminations, spalls, and exposed reinforcing steel. Identify areas of delaminated concrete by sounding.

- On slabs or box beams with no additional wearing surface, document the condition of the concrete on the top of the slab or box as part of the superstructure.

- Verify that tie rods are present and functioning properly.

Figure 4:4-46: Prestressed Concrete Box Beams With Heavy Deterioration and Severed Strands

Subsection 4.3.9 Prestressed Concrete Beam Bridges

Prestressed I-beams, T-beams, modified T-beams, and U-beams are commonly used as precast members. They use material efficiently by concentrating the concrete away from the beam's neutral axis where it is needed most for stiffness and strength. Concrete decks are often designed to act compositely with the beams, using shear connectors in the top flanges of the beams. They are used for simple spans up to about 150 feet in length. They may also be made continuous over piers. This is done by placing conventional reinforcing steel longitudinally in the deck over the piers to resist negative bending. The main steel prestressing strands are placed parallel to traffic and are located in the bottom flange of the beam, though some strands can be inclined upwards toward the beam ends. These are called draped or harped strands. Conventional reinforcing steel ties are placed transversely along the beam for shear reinforcement. Prestressed beam bridges generally include concrete diaphragms at the abutments and piers and either steel or concrete diaphragms within the spans.

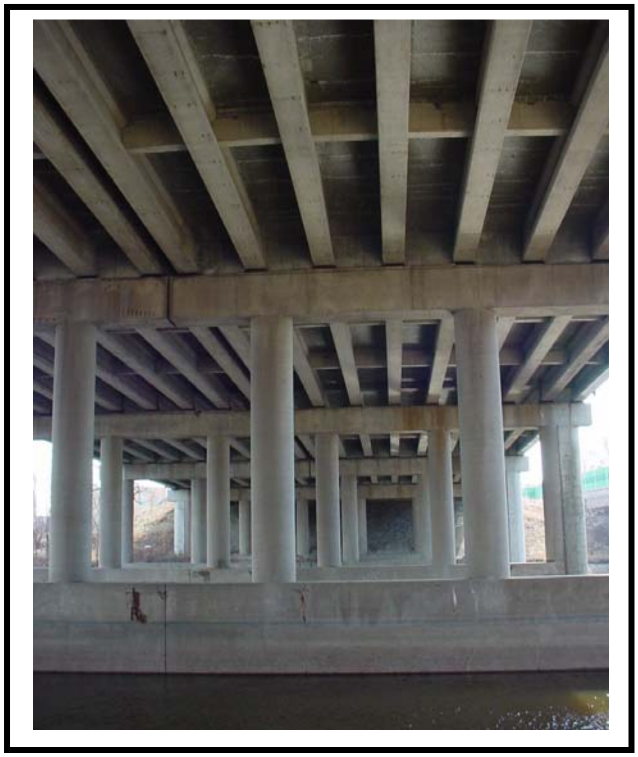


Figure 4:4-47: Prestressed Beams and Concrete Diaphragms

Figure 4:4-48: Shear Cracks on Precast Concrete Girders

Inspection of prestressed concrete beam bridges should include the following:

- Sight down the length of the beams to check for sagging. Sagging is a sign that the beam is losing its prestressing force and may be unable to carry the loads for which it was designed.
- Inspect each beam for cracks, noting the location, orientation, length, maximum width, and type of each. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks on a primary concrete member wider than 1/16 inch.
- Look for transverse flexural cracks on the beam underside in the positive moment regions. Their presence indicates a serious structural overload or loss of prestressing/post-tensioning force. Measure the crack widths and lengths and document their location.
- Look for longitudinal cracks at the interface of the web and top flange that are not substantially closed below any surface damage. This indicates permanent deformation of the stirrups.
- Examine the beam underside for parallel longitudinal cracks. These usually occur along the prestressing strands and may occur due to inadequate concrete cover. Rust stains that accompany the cracks suggest that the prestressing strands are corroding and debonding.
- Examine the beam ends for evidence of cracked or spalled concrete, sometimes accompanied with corroded reinforcing strands. This may occur due to leaking expansion joints that corrode the reinforcing or prestressing steel. It may also be the result of a lack of non-prestressed reinforcement in the zone of prestressing force transfer.
- Look for diagonal shear cracks on the beam sides near the abutments and piers.
- Look for vertical cracks on the beam sides near the abutments and piers. Vertical cracks in these areas suggest the bearing assemblies are restricting girder movement.
- Check the beams, especially the fascias, for traffic impact damage. Severe impacts that expose several prestressing strands may justify replacement of the beam.
- Look for delaminations, spalls, and exposed reinforcing steel.

Subsection 4.3.10 Concrete Box Girder Bridges

Box girder bridges are used for very long structures and curved spans. The sections are very large, and a single box can be used to carry an entire roadway. The inside of each box is usually large enough for an inspector to enter.

Traditional box girders are cast-in-place and may be conventionally reinforced or post-tensioned. Cast-in-place box girders will often contain several internal vertical webs and are referred to as multi-cell box girders.

The main reinforcement of post-tensioned box girders is a combination of conventional steel reinforcement and post-tensioning tendons. The post-tensioning tendons may be placed in the bottom flange, in the web walls, in both the bottom flange and the web walls, or not in the concrete at all. The post-tensioning tendons are normally placed within galvanized steel ducts that are filled with grout after stressing. Conventional reinforcing steel ties are placed transversely along the beam for shear and torsion reinforcement. In newer design, the deck is also post-tensioned, especially if there are wide cantilevers of the deck past the girder web walls.

Figure 4:4-49: Concrete Box Girder Under Construction

Segmental box girder bridges are similar to traditional box girders. However, the segments of segmental box girders are manufactured at a precast plant or on-site and erected individually. They commonly have a trapezoidal shape, with the top flange cantilevering over inclined webs. They normally contain only one cell and all are post-tensioned.

Figure 4:4-50: Crack in Box Girder Top Flange

Inspection of reinforced concrete box girders should include the following:

- Inspect each girder for cracks, noting the location, orientation, length, maximum width, and type of each. Document the location, length, and width of all cracks on sketches or prepared templates.
- All cracks should be checked to see if they are full-depth. Ultrasonic V-meter testing can be used to check for full-depth cracking, or the location of cracks inside and outside the box can be compared from the sketches or templates.
- Mark crack locations with the date the crack was found on the concrete.
- Look for transverse flexural cracks on the underside of the beam between supports and on top of the deck over the piers on continuously supported bridges. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks on a primary concrete member wider than 1/16 inch.
- Check for deteriorated concrete in the flexural zones that may be causing debonding of the reinforcing steel. This is especially critical near the ends of reinforcing steel bars, since a certain length of the bar must be embedded within sound concrete to fully develop its strength.
- Examine the support areas for shear cracks. Shear cracks will be diagonal, extending up from the bearing towards mid-span. Wide shear cracks suggest the loss of aggregate interlock, meaning the member could be hanging from the reinforcing stirrups.
- Check interior concrete diaphragms over pier bearings. Cracks here often extend full-depth through the web walls and floor.
- Look for vertical cracks on the girder sides near the abutments and piers. Vertical cracks in these areas suggest the bearing assemblies are restricting girder movement.
- Check the entire member for signs of corroding reinforcing steel, as indicated by rust stains or exposed reinforcement.
- Look for efflorescence. Note if it is stained with rust since this condition suggests reinforcing steel corrosion. Investigate the bearing areas for spalled concrete due to friction from thermal movement or crushed concrete due to bearing pressure overloads.
- Check members under drains or leaking expansion joints for cracks, delaminations, spalls, and exposed reinforcing steel.
- Verify that any drain holes are open.
- Look for delaminations, spalls, and exposed reinforcing steel.

- Check previously repaired areas for soundness by hammer tapping.
- Document any box girder top flange transverse flexural cracks and any leaching and rust staining that may accompany them. This will usually be performed during an in-depth inspection, as the underside of a box girder's top flange can only be seen from inside the cells.
- Look for collision damage, including scrapes on member undersides, chips, cracks, spalls, or a missing section of a member. Strong collisions may expose the reinforcing.

Figure 4:4-51: Diagonal Crack in Box Girder

The inspection of post-tensioned box girders should include all of the above items, as well as the following:

- Check for transverse flexural cracks on the girder underside in the positive moment regions. Post-tensioned members are in axial compression, so any transverse flexural crack indicates a structural overload or loss of post-tensioning force. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks on the girder.
- Sight down the length of the girders to check for sagging. Sagging is a sign that the beam is losing its post-tensioning force and may be unable to carry the loads for which it was designed.
- A detailed survey along the gutter lines and centerline should be conducted periodically as a part of a Special Inspection to compare measurements with as-built and previously measured elevations to assess sagging.
- Check for any super elevation irregularities on curved box girder bridges. This is a sign that torsional distress has occurred.

- Examine the girder underside for parallel longitudinal cracks. These may indicate reinforcing corrosion.
- Inspect the concrete at the anchorage zone for localized cracking. This may indicate inadequate detailing to resist the stressing forces.

Inspection of tension rods or post-tensioning cables should include the following:

- Look at the tensioning steel anchorages for lack of bearing or slip of the cable through the wedge. Sudden losses of force may allow the rod/cable to snap and shoot out of the anchorage.
- Pull/shake rod ends to check for looseness. Looseness indicates a complete loss of prestressing force.
- Lightly tap the tensioned length of the rod/cable (if accessible) with a rubber mallet. Similar to the strings of a guitar, tensioned members should ring, while detensioned members will produce a dull thud. As an alternative, the rods/cables may be shaken. Tensioned members should be taught. While performing these procedures, stand out of the way of the rod/cable in case it suddenly fails.
- Check any grouted anchors for soundness of the grout.
- Look for corrosion and document its extent.
- Look for broken rods/cables.
- Check section loss on the threads at the ends of a rod.
- Inspect the anchorage nuts for cracks or other damage.

Figure 4:4-52: Post-Tensioning Rods Protruding from the Anchorage, Indicating a Loss of Tensioning Force

Figure 4:4-53: Protruding Post-Tensioning Rod

SECTION 4.4 TIMBER SUPERSTRUCTURES

Timber was probably the earliest material ever used to construct a bridge. Modern timber can be configured into many superstructure types, including slab bridges, multi-beam bridges, arch bridges, and trusses.

Subsection 4.4.1 Timber Slab Bridges

Timber slab bridges are constructed using either glued laminated or nail-laminated sawn lumber placed longitudinally between supports. The slab acts as a single wide beam spanning from substructure unit to substructure unit. There are no individual beams with this type of bridge, so the slab acts as the deck and the superstructure. Slabs are used for simple spans of about 35 feet or less and for continuous spans of slightly greater lengths. Common glued laminated slab depths range from 6-3/4 inches to 14-1/4 inches thick, using individual strips of dimensional lumber 3/4 to two inches thick to form 42-inch to 54-inch wide panels. Nail-laminated slab depths range from eight inches to 16 inches deep, using two-inch to four-inch dimensional lumber. Timber slabs may have transverse distributor beams attached to their undersides as a method to distribute live loads across the bridge width. Steel transverse post-tensioning rods may also be used for this purpose, as well as to keep the planks in alignment on glued laminated slabs.

Inspection of timber slab superstructures should include the following:

- Examine the slab's top surface for signs of wear and abrasion, splitting, crushing, and decay.
- Examine all timber for accumulated moisture, staining, and vegetation.
- Examine all timber for signs of decay. Signs include discolored wood with a soft, rotted texture. Look also for fungi or plant life and depressed areas of the wood surface. Probe suspect areas. Drill or bore suspect planks to estimate the extent of decay.
- Examine all timber for signs of insect attack. Signs include piles of sawdust, small holes in the wood surface, insects, and a hollow sound when the beam is tapped with a hammer.
- Check the underside of the slab at the bearing areas. Crushing of the wood is usually the result of decay, but overloads may cause crushing of sound wood.
- Check the underside of the slab in tension areas for excessive deflections, fractures, and transverse cracks. These indicate excessive flexural stresses and overloads.
- Hammer tap random and suspect areas to evaluate the wood's soundness. A dull sound indicates deterioration.
- Probe test areas suspected to be experiencing decay. Lift a small sliver of wood from the surface using an awl, ice pick, or pocketknife. Wood that lifts up and splinters is sound, while wood that breaks up upon lifting the tool is decaying.

- Drill or bore suspect planks to estimate the extent of decay. Holes should be plugged with treated dowels after the inspection to prevent water and parasites from entering the timber's interior.
- Look for collision damage, including scrapes, cracks, or crushed areas.
- Look for fire damage, especially near the piers or abutments where fires can be built close to the beams. Fire damaged members that exhibit large strain deformations should be reported immediately to the District Engineer or the Inspection Consultant.
- Check fasteners (nails, bolts, lag screws, deck clips, etc.) for corrosion or slipping. Check suspect fasteners for looseness by striking with a hammer. The location of any missing fasteners should be noted.
- Sight along the length of the beam under traffic loads to look for excessive vertical or lateral deflections. Excessive deflections may indicate that the member cannot carry its original design load, or that other bridge members are damaged and additional load has shifted to the member in question. The measured or estimated amount of deflection should be recorded.
- Listen for unusual sounds with the passage of live loads.
- Examine any overlay for signs of wear, abrasion, cracks, potholes, and impending potholes.

Subsection 4.4.2 Timber Multi-Beam Bridges

Timber, solid, sawn multi-beam bridges are constructed using three or more beams as the primary members. Span lengths are limited by the longest available length of solid lumber, so they are usually used for bridge spans from 15 to 30 feet. Typical beam dimensions are four to eight inches wide and 12 to 18 inches deep. Solid wood blocking or bridging is normally placed between the beams to keep the beam in proper alignment. Due to the limited availability of large timbers of this size and the ready availability of high-quality glued laminated beams, solid, sawn multi-beam bridges are rarely built today.

Figure 4:4-54: Two-Span Timber Bridge

Figure 4:4-55: Solid, Sawn Multi-Beam Bridge

Timber glued laminated multi-beam bridges are similar to sawn multi-beam bridges, except that the beams are pre-manufactured members. The beams are made by bonding several strips of wood together with a waterproof structural adhesive to form a built-up beam. By using 3/4-inch to two-inch thick strips of wood for the laminations, natural wood defects may be placed in a non-critical location or may be eliminated completely from the final product. The result is a fairly uniform beam with strength properties greater than solid wood of similar dimensions. Standard three-inch to 14-1/4-inch wide beams are common, and depths are limited only by transportation and pressure treating considerations. Clear spans up to 150 feet have been attained, though spans less than 80 feet are more common.

Inspection of timber beam bridges should include the following:

- Notify the District Engineer or the Inspection Consultant of any transverse crack or notable deflection on any timber beam.
- Check for member crushing at the abutments and piers. These are the most suspect areas because they tend to collect and retain the most moisture and debris, creating ideal environments for plant and fungal growth and insect attack. Overloads can cause crushing of sound wood. Notify the District Engineer or the Inspection Consultant of excessive crushing.
- Look for shear-related damage at and near the supports. Overloads result in high-shear stresses that cause horizontal splits to form along the length of the beam, approximately mid-height.
- Examine the high-flexural regions of the beam for signs of overload damage such as crushing of surfaces in compression and transverse cracking of surfaces in tension.
- Examine all timber for signs of decay. Signs include discolored wood with a soft, rotted texture. Look also for fungi or plant life and depressed areas of the wood surface. Probe suspect areas. Drill or bore suspect members to estimate the extent of decay.

- Look for any delaminations of individual wood strips in glued laminated beams. Because debonding that extends through the beam width changes the original deep, stiff member into two smaller flexible members, this type of deterioration can be especially serious.
- Examine all members for signs of insect attack. Signs include piles of sawdust, small holes in the wood surface, insects themselves, and a hollow sound when the beam is tapped with a hammer.
- Look for fire damage, especially near the abutments where fires can be built close to the beams. Document any section loss.
- Check fasteners (nails, bolts, lag screws, deck clips, etc.) for corrosion or slipping. Check suspect fasteners for looseness by striking with a hammer. The location of any missing fasteners should be noted.
- Sight along the length of the beam under traffic loads to look for excessive vertical or lateral deflections. Excessive deflections may indicate that a member cannot carry its original design load or that additional load has shifted to the member in question. The measured or estimated amount of deflection should be recorded.
- Listen for unusual sounds with the passage of live loads.
- Examine any overlay for signs of wear, abrasion, cracks, potholes, and impending potholes.
- Look for collision damage, including scrapes, cracks, or crushed areas.

Subsection 4.4.3 Timber Trusses, Covered Bridges, and Arches

Timber truss bridges are structures with two parallel trusses as the main load-carrying members. Covered bridges are truss bridges with a wood covering to prevent decay of the superstructure. Spans up to 250 feet are attainable. The deck is typically placed between the trusses. These are called through trusses when there is overhead lateral bracing, or pony trusses when there is no overhead lateral bracing. The deck may also be placed on top of the trusses. These are called deck trusses. Modern connections are made with steel bolts and gusset plates. Older trusses generally used bolts or wooden peg connections. To keep the two trusses in line longitudinally, secondary lateral bracing members diagonally connect the bottom chords. For deck and through trusses, the top chords are braced diagonally as well. Lateral bracing may be made of wood, wrought iron, or steel. Sway bracing keeps the two trusses in line laterally. On deck and through trusses, sway bracing transversely frames between the truss verticals. On pony trusses, sway bracing is usually placed as a transverse diagonal on the outsides of the trusses. It connects the top chord to transverse “outrigger” floor beam extensions and functions to prevent buckling of the top chord. Sway bracing is normally made out of wood. Truss members are theoretically loaded in either pure tension or pure compression. Truss diagonals and verticals may be timber or a combination of timber for compression members, and steel or wrought iron rods for tension members.

Loads are delivered to the trusses by way of floor beams spanning transversely between these main load-carrying members. Figure 4:4-57 provides several elevation views of typical timber covered bridges.

Modern timber arch bridges are constructed of curved glued laminated main members. Wood arches use two hinges for spans up to approximately 80 feet and three hinges for spans up to approximately 300 feet. Wood arches are most commonly used as pedestrian bridges, although they have been built for highway use. Most older timber arches were constructed with a series of individual truss-like arched segments.

Arch bridges can be deck arch, though arch, or tied arch structures and are loaded in combined compression and bending. Loads are delivered to the arches by way of floor beams spanning transversely between these main load-carrying members. Many old timber covered bridges in Indiana are composed of both a truss and an arch that work together in carrying dead load and live load.

Figure 4:4-56: Timber Covered Bridge

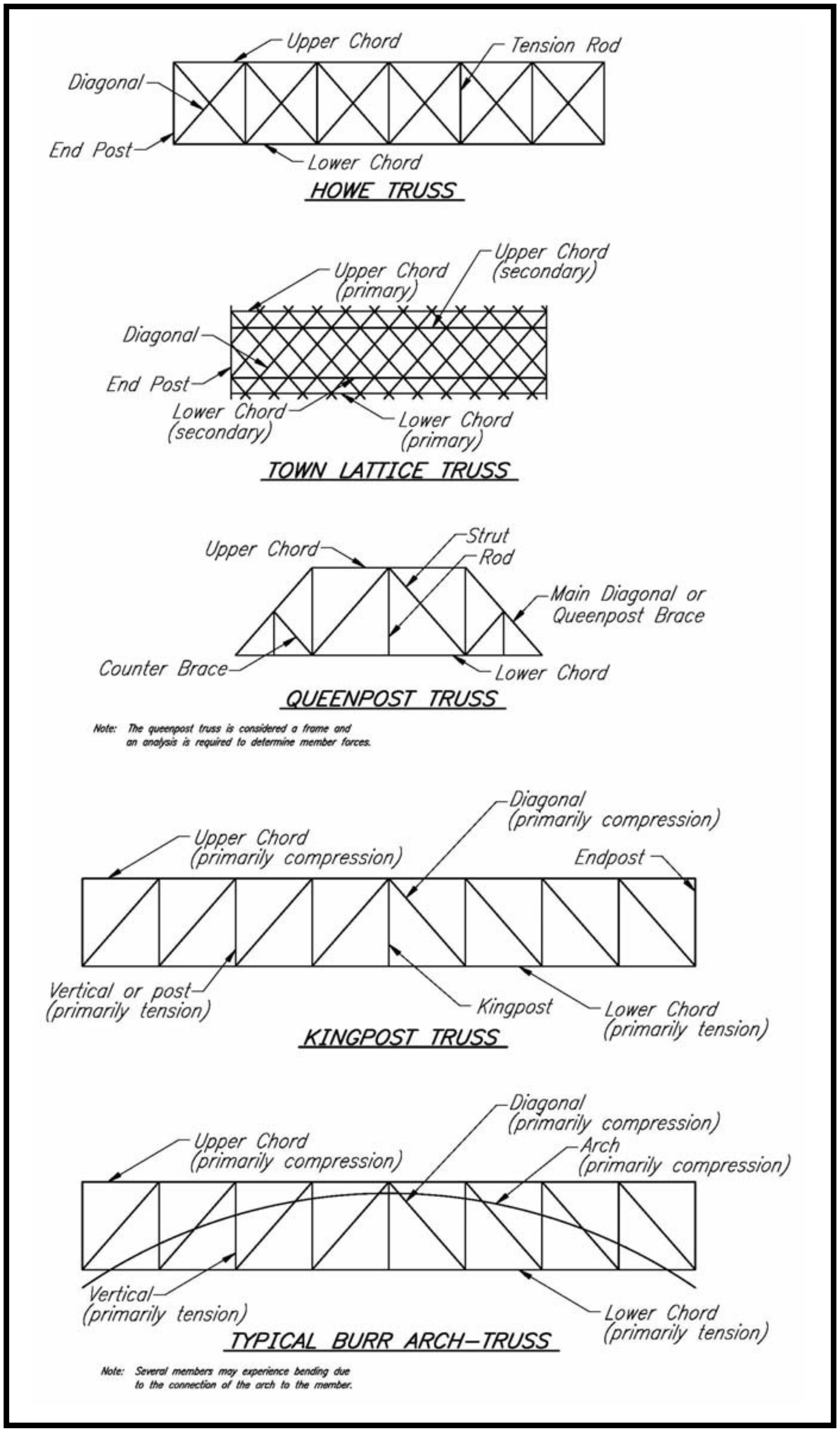


Figure 4:4-57: Common Timber Covered Bridge Elevations

Most covered bridges contain numerous members oversized for the original design load. Ease of fabrication and construction was a primary concern for these bridges and efficiency in member sizing was often not a consideration. These bridges were often designed for the controlling diagonal member and, thus, all subsequent diagonal members were made the same size. This practice was followed for all the members. This means only one or two of each member type are controlled by design loads, and the remaining members are progressively oversized. This provided uniform connection types and dimensions throughout the structure. A schematic illustrating the typical locations for the maximum forces in a Burr arch truss are provided in Figure 4:4-58.

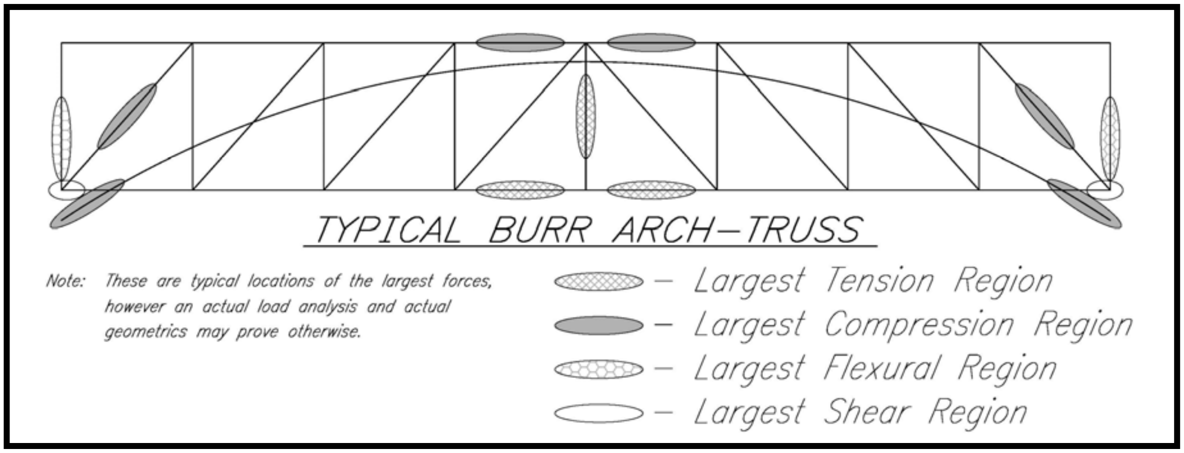


Figure 4:4-58: Typical Burr Arch Truss

The Town lattice truss provides a unique design feature. Due to the redundancy in the members, each main truss member can globally be considered as one large timber beam. The top and bottom chords can be considered flanges of a simple beam, and the diagonals can be considered the web. Figure 4:4-59 demonstrates this concept. The extensive redundancy in this design permits the truss to function well after several members show signs of deterioration or damage.

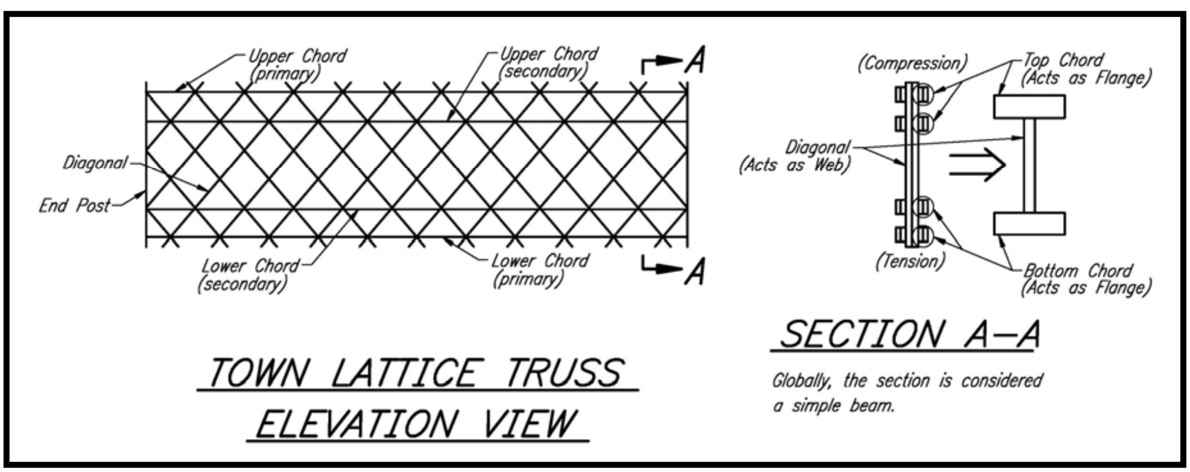


Figure 4:4-59: Town Lattice Truss

Historically, the majority of timber truss failures were due to failure of a connection, not the member. Failure of a connection may prove detrimental to the entire bridge if adequate redundancy is not present. Movement over time, deterioration, large loadings, and poor details all are factors that lead to connection problems. The notching of vertical members to accommodate the connection to the diagonal is a common example of a poor detail that can contribute to a failure. This notching minimizes the section of the vertical member in an area where large compression and tension forces place this detail in a high shear zone. Figure 4:4-60 and Figure 4:4-61 illustrate this type of failure.

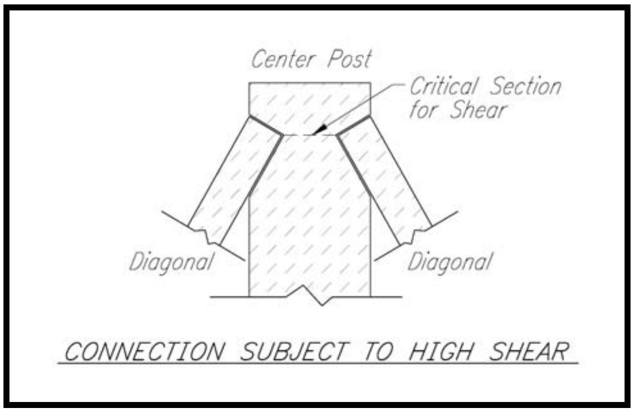


Figure 4:4-60: High-Shear Timber Connection

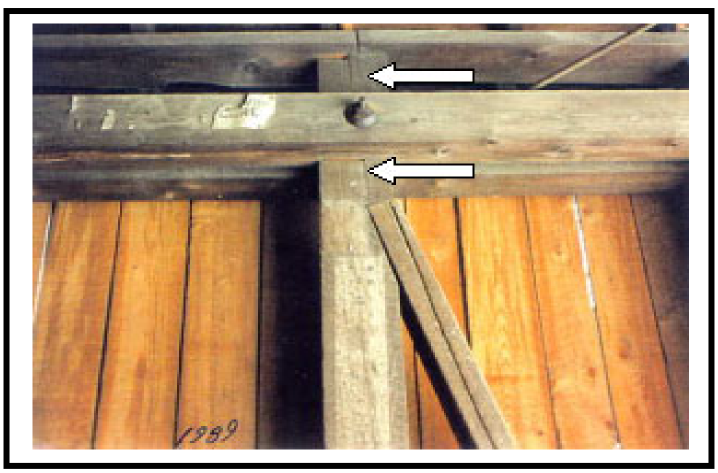


Figure 4:4-61: Shear Failure at Connection

Another typical area for connection weakness is the bottom portion of the vertical member at the floor beam or lower chord. This area is subject to high shear forces and may be exposed to high water and debris damage, as well as the elements. Often the members are notched to allow for the connection, further weakening the member. Weakening of this connection may lead to the failure of the floor beam or lower chord at the connection. Figure 4:4-62 illustrates a heavily damaged vertical member/floor beam connection.

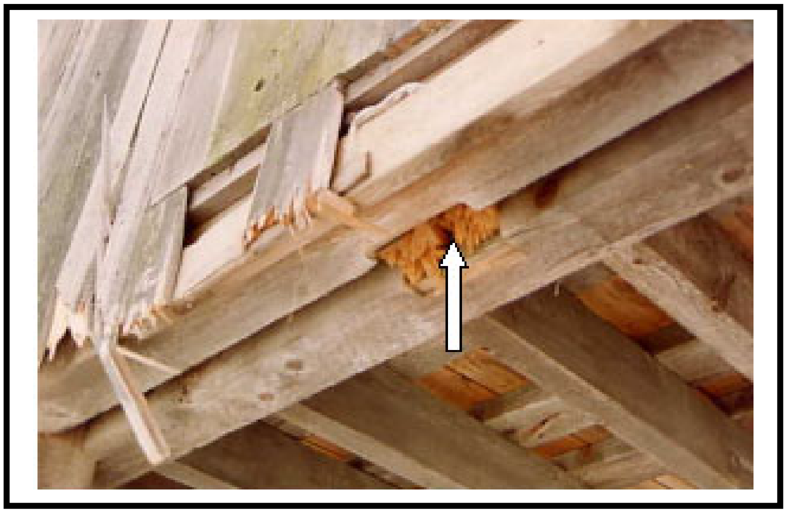


Figure 4:4-62: Failing Bottom Chord/Vertical Connection

Most covered bridges require splices of the lower chord, upper chord, and arch. These areas are subject to high stresses and often have a smaller cross-sectional area due to the notching required to form the splice. Splices can either occur in a member, or within the connection and should be reported accordingly. The splices will often indicate signs of overstressing or signs of deterioration from any movement or separation of the members. Timber splitting adjacent to the splice may be present and should be monitored for deterioration.

Figure 4:4-63: Typical Splice Detail

Bearing areas often show signs of deterioration. Numerous timber trusses utilized bearing beams. The original designers often used these beams as a sacrificial detail that would be exposed to dirt and debris, while keeping the main structural members free from deterioration. The designer anticipated these members would be replaced when they deteriorated. In practice, many of these members were left in place. This deterioration could prove detrimental to the main structural members. Figure 4:4-64 illustrates typical sacrificial bearing members.

Figure 4:4-64: Sacrificial Bearing Beams

Secondary members such as cross bracing, sway bracing, and the roof members also play a role in the overall integrity of the bridge and should not be overlooked in an inspection. These members provide lateral stiffness in the bridge and help prevent movement of members and joints. Secondary members help resist loads such as snow and wind loads that are negligible in most bridges, but can serve as potentially fatal loading conditions in covered bridges. The large surface area exposed to wind promotes large horizontal loads that can contribute to the failure of a covered bridge.

The roof may collect heavy snow that can lead to large additional gravity loads on the bridge. The additional snow load, in conjunction with a large live load, can overstress the connections or members of a covered bridge.

Inspection of timber trusses, covered bridges, and arches should include the following:

- Thoroughly inspect all connections and document any deficiencies or movement in each member.
- Check the truss bottom chord members for crushing at the abutments. These are the most suspect areas because they tend to collect and retain the most moisture and debris, creating ideal environments for plant or fungal growth and insect attack. Overloads can cause crushing of sound wood. Notify the District Engineer or the Inspection Consultant of excessive crushing.
- Look for any delaminations of individual wood strips in glued laminated members. Debonding occurring in the vicinity of connectors can be serious if the member is carrying tensile loads.
- Examine the entire member for signs of insect attack. Signs include piles of sawdust, small holes in the wood surface, insects, and a hollow sound when the member is tapped with a hammer.
- Look for fire damage, especially near the abutments and arch bearings where fires can be built close to the primary load-carrying members. Document any section loss.

- Check fasteners (nails, bolts, lag screws, deck clips, etc.) for corrosion or slipping. Check for loose fasteners by striking with a hammer. The location of any missing fasteners should be noted.
- Sight along the length of a truss or arch under traffic loads to look for excessive vertical or lateral deflections and out-of-plumb members. Excessive deflections indicate that the member may not be able to carry its original design load, or that other bridge members are damaged and additional load has shifted to the member in question. The measured or estimated amount of deflection should be recorded.
- Examine each member for signs of decay. Signs include discolored wood with a soft, rotted texture. Look also for brooming and depressed areas of the wood surface. Probe areas suspected to be experiencing decay. Drill or bore suspect planks to estimate the extent of decay.
- Look for collision damage including scrapes, cracks, or crushed areas.
- Check the arch/spandrel column interface for bearing failures. Bearing failures on timber members loaded parallel to the grain will “broom out.”
- Check the mid-height of the spandrel columns for flexural cracks, which is a sign of structural overloads or differential arch deflection.
- Look for any splitting of sawn timber members. Excessively long or wide splits may be a sign of a structural overload.
- Sight all columns to check for bowing. Excessive deflections indicate that the member has been overstressed or that the bridge is experiencing differential settlements. The measured or estimated amount of deflection should be recorded.
- Note any protective systems such as preservatives or retardants.

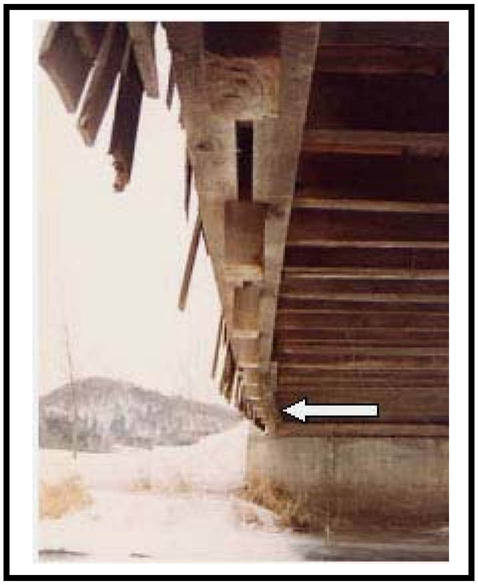


Figure 4:4-65: Lateral Displacement of Members

Figure 4:4-66: Movement at Connection

Figure 4:4-67: Movement at Connection in Lower Chord

Subsection 4.4.4 Rods and Cables Used in Timber Superstructures

Rods and cables are used as truss members, to post-tension timber structures, or to support timber members. These members may be considered to be fracture critical if a failure would result in a collapse or partial collapse of the bridge. The inspection of any rods and cables should include the following:

- Check for corrosion and document its extent. Severe corrosion will produce section loss and an increase in tensile stresses.
- Look for broken rods/cables.
- Pull/shake rod ends to check for looseness. Looseness indicates a complete loss of post-tensioning force.
- Lightly tap the tensioned length of the rod/cable (if accessible) with a rubber mallet. Similar to the strings of a guitar, tensioned rods and cables should ring, while detensioned members will produce a dull thud. As an alternative, the rods/cables may be shaken. Tensioned members should be taught. While performing these procedures, stand out of the way of the rod/cable in case it suddenly fails.
- Inspect the anchorage nuts for cracks or other damage.
- Inspect anchorage and bearing areas for signs of crushed wood.

Figure 4:4-68: Anchor Bolts for Steel Vertical Tie Rod

Figure 4:4-69: Steel Vertical Tie Rods on Timber Covered Bridge

Figure 4:4-70: Upper Connection for Steel Vertical Tie Rods on Timber Covered Bridge

Subsection 4.4.5 Special Inspections for Timber Covered Bridges

Indiana requires a Special Inspection for each timber covered bridge. These bridges are not load-path redundant. They generally have low load-carrying capacities, and a more detailed inspection supports the preservation efforts of these historical bridges. The Special Inspection report will help identify problems and assist the owner in maintaining and preserving the bridge.

All main load-carrying members and connections/panel points are inspected and documented as a part of the Special Inspection. Floor beam connections are also inspected and documented as a part of this inspection. There are many connection details and connection types and it is up to the Inspection Team Leader to determine and distinguish between the member and the connection. Typically, the connection is defined as being 12 inches outside of the connection bolt, connection plate, or change in cross-sectional area for the connection, and the remaining portions are defined as the actual member. Figure 4:4-72 provides guidance on several common typical connection details.

Secondary members such as lateral bracing, roof members, stringers, and floor beams should be thoroughly inspected during the Routine Inspection and are not considered part of a Special Inspection. It is recommended, but not required, that a brief discussion of secondary members and associated repairs and conditions be provided in the Special Inspection report.

Figure 4:4-71: Covered Bridge in Carroll County, Indiana

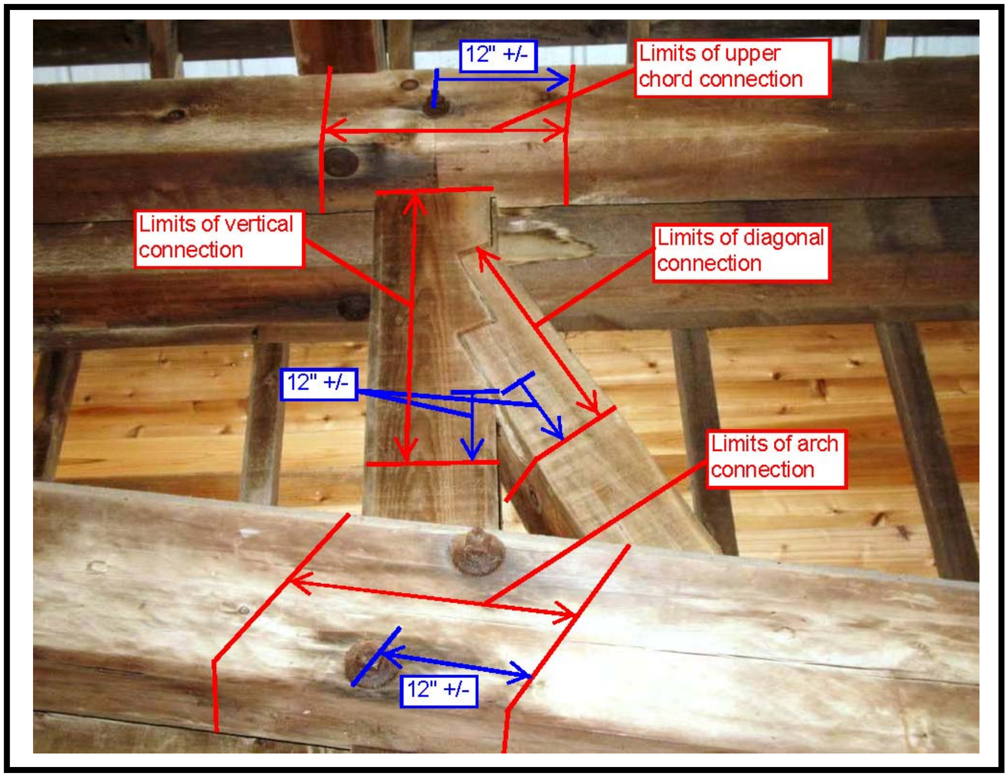


Figure 4:4-72: Standard Connection Limits

The guidelines listed in this section are the minimum reporting requirements for acceptance of a Special Inspection. Although, these minimum requirements must be met for acceptance of the report by INDOT, the inspecting agency may provide alternate report formats meeting internal guidelines as long as the criteria set forth in this chapter are met. An example inspection report has been provided in Appendix C. A Special Inspection report must include the following as a minimum:

- An inspection Plan of Action should include the following:
  - Sketches of the superstructure with locations of main members and connections clearly identified, along with an elevation view for trusses with locations labeled by letters and numbers similar to the nomenclature indicated in Part 4, Chapter 11
  - A north arrow on the sketch
  - A list of all members and connections to be inspected
  - A brief historical fact statement
  - All inspection tools and access equipment required for the inspection
  - Traffic control requirements
  - Bridge cleaning requirements

  - Other items that should be reviewed and made available to the inspector, if available, prior to the inspection, including the following:
    - Existing bridge plans and any repair/rehabilitation plans
    - Prior load ratings
    - Historical data and maintenance history of the bridge
    - Prior inspection reports

- A general statement discussing inspection procedures
- Date, temperature, and weather conditions of the inspection
- Time duration of the inspection
- Inspection Team Leaders and Inspection Team Members present at the inspection
- A summary of inspection results for all members and connections that show deterioration, deficiencies, or required monitoring
- Documentation of inspection results for each individual member, panel point, connection, and/or component, including the following:
  - Individual member rating
  - Noted deficiencies
  - A brief statement discussing the presence or lack of distress
- Testing performed and locations of the tests
- Recommendations for repairs and maintenance, highlighting urgent repairs and listing programmed repairs and maintenance
- Photographs of the bridge, including an approach and elevation photograph, and any posting signs
- Photographs of members or components assigned a condition rating of 4 (Poor) or less
- Photographs of problem areas warranting repair and/or monitoring
- Recommended inspection interval

SECTION 4.5 MASONRY ARCHES

The only masonry bridge superstructure form is the arch. Masonry arches have been used for building and bridge construction since ancient times. Current use of some of these structures is a testament to their durability. See Figure 4:4-73 for a picture of a masonry arch, and Figure 4:4-74 for masonry arch components.

Figure 4:4-73: Masonry Arch

Stone masonry arches receive both compressive and bending moments. Since an arch carries a high degree of compressive load, there should be little, if any, net tension along its cross section. Because of this, there should be no cracking at any of the masonry mortar joints due to bending moments.

Masonry arches are closed spandrel structures that have a single, solid barrel forming the primary load-carrying member. Fill material is placed on top of the arch to support the roadway, and spandrel walls are used to retain this fill. Spandrel wall failure would cause the fill to spill out, resulting in roadway settlement.

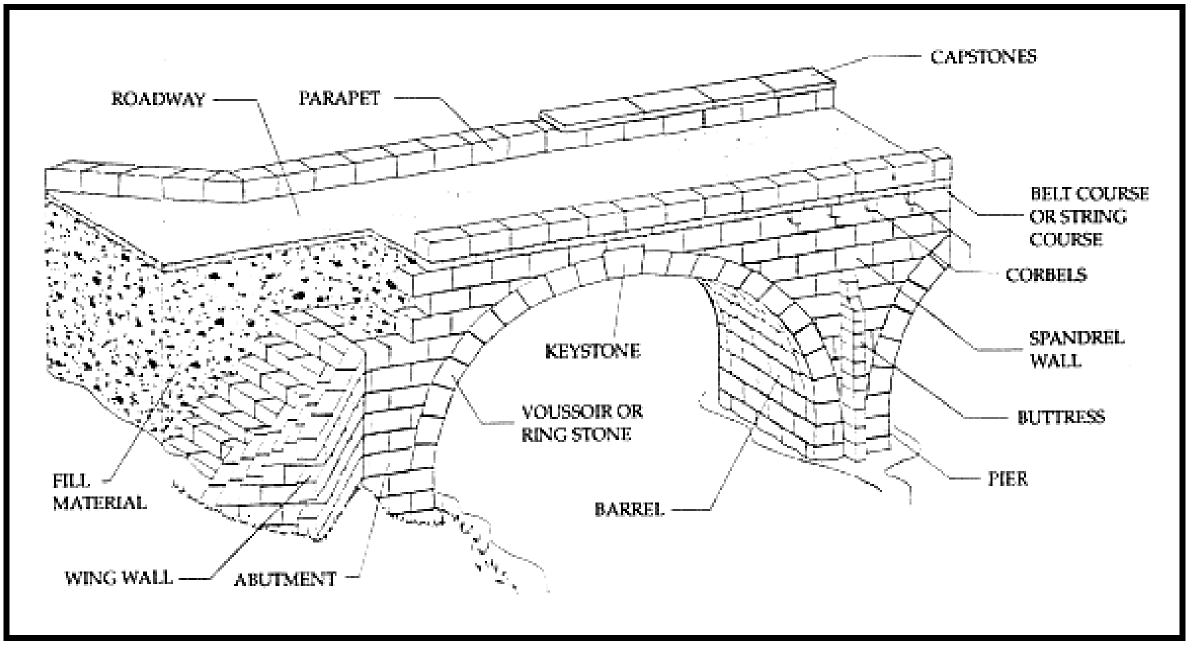


Figure 4:4-74: Masonry Arch Components

Inspection of masonry arches should include the following:

- Examine the bearing/spring line areas for signs of crushed masonry, since the highest compressive forces experienced by an arch are found at the spring line. Missing or crushed masonry units result in a loss of arch cross-sectional area, increasing the axial stresses.
- Look for crushed or missing masonry units and mortar. This would suggest a possible overload. Missing or crushed mortar results in a loss of arch cross-sectional area, increasing the axial stresses, and allows masonry units to move relative to one another.
- Check the arch and spandrel wall surfaces for bulges. This defect suggests unstable soil, and the roadway above will also likely show signs of settlement. A bulge or flatness in the arch indicates that it is not functioning properly. Significant areas of bulging should be reported immediately to the District Engineer or Inspection Consultant.
- Look for cracked, broken, or deteriorated masonry units and mortar. This would suggest weathering due to freeze/thaw effects.
- Check the entire arch for transverse mortar cracks. These are the result of excessive bending moments or arch support settlements.
- Check for longitudinal cracks in the abutments. These indicate differential settlement. Contact the District Engineer or Inspection Consultant if cracks over 1/8 inch wide are found.
- Look for flattening of the arch.

- Check for cracks in the spandrel walls near the quarter points. These indicate flexibility of the arch barrel over the center half of the span.
- Look for leaching along the entire arch and the spandrel walls. This indicates water is flowing through the mortar joints and leaching minerals. Long-term leaching will weaken the mortar.
- Check areas exposed to drainage and roadway runoff. The runoff may cause scaling.
- Check to make sure weep holes in the arch are functioning.
- Check to make sure surface drains are functioning properly and are not allowing water to penetrate the fill.
- Check for loss of fill material. Potholes in the roadway indicate loss of fill.
- Look for collision damage, including scrapes, cracks, or crushed areas.
- Examine previous repair areas for soundness.

Figure 4:4-75: Closed-Spandrel Masonry Arch

SECTION 4.6 NBI SUPERSTRUCTURE RATING

The NBI numeric condition rating describes the existing superstructure components as compared to their as-built condition. Ratings range from 9 to 0, with 9 describing components in excellent condition, and 0 describing failed components that cannot, or should not, be repaired.

Because only a single number is used to rate the superstructure, the rating must characterize its overall general condition. The rating should not be used to describe local areas of deterioration, such as isolated heavy corrosion, or a bent flange due to a traffic impact. However, widespread heavy corrosion or widespread cracked welds would certainly influence the rating. A proper rating will consider deterioration severity, plus the extent to which it is distributed throughout the superstructure.

NBI ratings are used to evaluate the state of deterioration of the superstructure material. Postings or original design capacities less than current legal loads will not influence the rating. Similarly, temporary superstructure support does not change or improve the condition of the superstructure material and will not influence the superstructure rating.

Decks that are built integral with the superstructure, such as steel or concrete box girders and decks of reinforced concrete girder bridges, are rated as separate components from the superstructure, but the superstructure rating may be affected by the deck condition. The resultant superstructure condition rating may be lower than the deck condition rating where the girders have deteriorated or been damaged.

On slab bridges, the deck is the same structural component as the superstructure, and the NBI condition ratings for the deck and superstructure must be the same.

Indiana has developed supplemental rating guidelines to assist the inspector in properly assigning condition ratings to specific components constructed of the most commonly used materials. The general condition ratings, along with the Indiana supplemental rating guidelines for superstructures, are as follows:

Code (Rating) **Description**

N **NOT APPLICABLE:**

Supplemental Rating Guidelines: Used for underfill structures only.

9 **EXCELLENT CONDITION:**

Supplemental Rating Guidelines: Superstructures are properly constructed and in new condition.

8 **VERY GOOD CONDITION:** No problems noted.

Supplemental Rating Guidelines:

Concrete Superstructure – There are no noteworthy deficiencies which affect the structural capacity of the members.

Prestressed Concrete Superstructure – There are no cracks, stains, or spalls.

Steel Superstructure – There are no noticeable or noteworthy deficiencies which affect the condition of the superstructure.

Timber Superstructure – There are no noteworthy deficiencies which affect the structural capacity of the members.

7 **GOOD CONDITION:** Some minor problems exist.

Supplemental Rating Guidelines:

Concrete Superstructure – Some minor problems are present. Nonstructural hairline cracks without disintegration may be evident. The load-carrying capacity of structural members is unaffected.

Prestressed Concrete Superstructure – Nonstructural hairline cracks less than 0.015-inch may be present. No rust stains are present.

Steel Superstructure – Some rust may be evident without any section loss.

Timber Superstructure – Minor decay, cracking, or splitting of beams or stringers at noncritical locations may be present.

6 **SATISFACTORY CONDITION:** Structural elements show some minor deterioration.

Supplemental Rating Guidelines:

Concrete Superstructure – Structural members show some minor deterioration or collision damage. Hairline structural cracks or spalls may be present with evidence of efflorescence. Minor water saturation marks may be present. Generally, the reinforcing steel is unaffected.

Prestressed Concrete Superstructure – Minor concrete damage or deterioration is less than five percent. Few shrinkage cracks are present, and those that exist are tight and narrow. No shear cracks are present. Nonstructural cracks are over 0.015-inch. Isolated and minor exposure of mild steel reinforcement may be present. No prestressing strands are exposed.

Steel Superstructure – Rusting is evident, but with minor section loss of less than two percent of thickness in critical areas.

Timber Superstructure – Some decay may be present, along with cracking or splitting of beams or stringers. Fire damage is limited to surface scorching with no measurable section loss.

5 **FAIR CONDITION:** All primary structural elements are sound, but may have minor section loss, cracking, spalling, or scour.

Supplemental Rating Guidelines:

Concrete Superstructure – Structural members are generally sound, but may have evidence of deterioration or disintegration. Numerous hairline structural cracks or spalls may be present, with minor section loss of reinforcing steel possible.

Prestressed Concrete Superstructure – Up to five pcernt of prestressing strands are exposed. Less than 15 percent of any area is spalled or delaminated. Multiple shrinkage cracks are present. No shear cracks or transverse cracks are present. Hairline longitudinal cracks may be present across the bottom flange. There is leakage at the joints with light efflorescence, but no staining.

Steel Superstructure – There is section loss, but less than five percent of the thickness in critical areas of primary members. Fatigue or out-of-plane distortion cracks may be present in noncritical areas. Hinges may be showing minor corrosion problems.

Timber Superstructure – Moderate decay, cracking, splitting, or minor crushing of beams or stringers may be present. Fire damage is limited to surface charring with section loss of less than five percent of the member section.

4 **POOR CONDITION:** Advanced section loss, deterioration, spalling, or scour may be present.

Supplemental Rating Guidelines:

Concrete Superstructure – There is extensive deterioration. There are measurable structural cracks or large spall areas. Corroded reinforcing steel is evident with measurable section loss. Structural capacity of some members is diminished.

Prestressed Concrete Superstructure – Five to 15 percent of prestressing strands are exposed. Fifteen to 25 percent of the area is spalled or delaminated. Multiple shrinkage cracks are present, including enlarging with possible minor spalls. Tight shear cracks may be present. Hairline transverse flexural cracks across the bottom flange may also be present. Longitudinal cracks with minor efflorescence or minor rust stains may be present along the bottom flange. Transverse tendons may be loose or heavily rusted. There may be leakage at the joints with heavy efflorescence or minor rust stains. Vertical or diagonal web cracks are less than three-inches long near the open joints in the barrier.

Steel Superstructure – There is significant section loss between five percent and 25 percent, of the member section in critical areas of primary members. Fatigue or out-of-plane distortion cracks may be present in critical areas. Hinges may be frozen from corrosion. Load-carrying capacity of structural members may be affected. There may be local buckling in compression members or connections. Tension flanges or members may show elongation.

Timber Superstructure – Extensive decay, cracking, splitting, crushing of beams or stringers, or significant fire damage may be present. A diminished load-carrying capacity of members is evident. Member section loss is between five percent and 25 percent.

3 **SERIOUS CONDITION:** Loss of section, deterioration, spalling, or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in the steel or shear cracks in the concrete may be present.

Supplemental Rating Guidelines:

All Superstructures – Bearing movement or deterioration threatens the stability of the superstructure.

Concrete Superstructure – There is severe deterioration and/or disintegration of primary concrete members. Large structural cracks may be evident. Reinforcing steel is exposed with advanced corrosion and significant section loss. Local failures or loss of bond are possible.

Prestressed Concrete Superstructure – Any sagging or loss of camber may be present. Severed, heavily corroded, or deformed prestressing strands, with over 15 percent of prestressing strands exposed, may be present. Over 25 percent of the area may be spalled or delaminated. Multiple shrinkage cracks are present and are wide with spalls. Some moderate-width shear cracks are present. Open transverse flexural cracks in the bottom flange may be present. Longitudinal cracks with minor efflorescence or minor rust stains may be present across the bottom flange. Vertical or diagonal web cracks greater than three-inches long may be present.

Steel Superstructure – Severe member section loss of over 25 percent, or cracking in critical areas of primary members, may be present. Minor failures may have occurred. Significant weakening of the primary members is evident. There may be global buckling of a primary member or connection. A primary member has a crack of two inches or longer. There are cracks in a gusset plate or welds that have, or may have, propagated into primary members. There are cracks in a hanger assembly member. The connection between railroad flat cars has failed.

Timber Superstructure – Severe decay, cracking, splitting, crushing of beams or stringers, or major fire damage may be present. Member section loss is over 25 percent. Load-carrying capacity is substantially reduced. Local failure may be evident.

2 **CRITICAL CONDITION:** Advanced deterioration of primary structural elements may be present. Fatigue cracks in steel or shear cracks in concrete may be present, or scour may have removed substructure support. Unless closely monitored, it may be necessary to close the bridge until corrective action is taken.

Supplemental Rating Guidelines:

Concrete Superstructure – Advanced deterioration of primary concrete members may be present. There is concrete disintegration around reinforcing steel with loss of bond. Some reinforcing steel may be ineffective due to corrosion or loss of bond. Numerous large structural cracks may be present. Localized failures of bearing areas may exist.

Prestressed Concrete Superstructure – Critical damage to the concrete or the reinforcing structures may be present. Multiple shrinkage cracks, spalls with exposed reinforcing, and/or rust may be present. Wide shear cracks and/or rust may also be present. Open cracks across the bottom flange and possibly into the web may exist. An abrupt lateral offset as measured along the bottom flange or lateral distortion of exposed prestressing strands. Excessive vertical misalignment may be present. Longitudinal cracks at the interface of the web and top flange that are not substantially closed below the surface damage (this indicates permanent deformation of the stirrups) may be present.

Non-Composite Prestressed Concrete Adjacent Box Beams – Any condition worse than described for Condition 3, above, is present.

Steel Superstructure – Severe section loss of over 50 percent of thickness is present at numerous locations with through thickness section loss at some critical locations of primary members. Extensive fatigue cracking may also be present.

Timber Superstructure – Severe decay, cracking, splitting, crushing of beams or stringers, or major fire damage has resulted in significant local failures. Unless closely monitored, it may be necessary to close the bridge until corrective action is taken.

1 **“IMMINENT” FAILURE CONDITION:** Major deterioration or section loss is present in the critical structural components or obvious vertical or horizontal movement affecting structural stability is present. The bridge is closed to traffic, but corrective action may put it back into light service.

Supplemental Rating Guidelines:

Concrete Superstructure – The bridge is closed to traffic. There is major deterioration or section loss present on primary structural elements. Obvious vertical or horizontal movement is affecting the structure’s stability.

Prestressed Concrete Superstructure – Critical damage requiring the replacement of a member is present. The bridge is closed to traffic. Temporary falsework to safeguard the public and the bridge should be installed.

Steel Superstructure – The bridge is closed.

Timber Superstructure – The bridge is closed.

0 **FAILED CONDITION:** The bridge is out-of-service and beyond corrective action.

One method of establishing a superstructure rating is to identify phrases within the guideline language that describes a superstructure condition more severely than what actually exists. The correct rating number will be one number higher than the one describing the more severe condition.

Another method to help narrow down the superstructure rating number is to group the numbers in general categories. Ratings of 9 to 7 apply to superstructures in good condition, 6 to 5 suggest fair condition, 4 to 3 suggest poor condition, 2 suggests poor/critical condition, and 1 to 0 suggest critical condition and the bridge being closed to traffic. There is a significant change from a superstructure in condition rating 5 (minor section loss, but structural elements sound) to condition rating 4 (advanced section loss and advanced deterioration).

SECTION 4.7 ADDITIONAL SUPERSTRUCTURE RATINGS

For state-owned bridges, each of the following items shall be rated as a stand-alone item, assessing its condition independently, and not how it might relate to Item 59, the NBI superstructure condition rating. Each item shall be rated as follows unless noted:

N **Not Applicable**

9 **Excellent Condition**

8 **Very Good Condition**

7 **Good Condition**

6 **Satisfactory Condition**

5 **Fair Condition**

4 **Poor Condition**

3 **Serious Condition**

2 **Critical Condition**

1 **Imminent Failure Condition**

0 **Failed Condition**

ITEM 59A.01 – BEARING RATING

Bearings carry the dead loads and live loads from the superstructure members to the substructure and accommodate bridge rotation, expansion, and contraction. Bridge movement can result from temperature changes, substructure movement, live and dead load deflections, wind loads, or quick braking of a vehicle. Movable (expansion) bearings accommodate superstructure longitudinal and rotational movements. Fixed bearings accommodate superstructure rotational movements only. Many bearing types are used in Indiana, including elastomeric bearings, rocker bearings, roller bearings, pot bearings, and various sliding plate type bearings.

Inspection of bearings should include the following items:

- Check for overall deterioration of the bearing.
- Check for bearing misalignments. Improper alignments suggest a failing bearing, excessive superstructure movement, substructure settlement, or improper construction. Signs of improper alignment include:

- A superstructure that is tight against the backwall of the abutment.
- Excessive overhang of the top sliding plate over the bottom sliding plate. The sole plate of a sliding plate bearing should normally line up with the masonry plate between temperatures of 60 to 70 degrees Fahrenheit.
- Unstable or improperly tipped rockers. The top of the rocker should be tipped away from the fixed bearing on hot days and towards the fixed bearing on cold days. Rockers are normally set vertical between temperatures of 60 to 70 degrees Fahrenheit.

Figure 4:4-76: Unstable Rocker Bearing

- Improperly positioned rollers. Rollers should be rolled away from the fixed bearing on hot days and towards the fixed bearing on cold days. Rollers are normally positioned on the centerline of the masonry plate between temperatures of 45 to 65 degrees Fahrenheit.

- Measure the distance from the girder/beam/truss to the backwall of the abutment.
- Measure the longitudinal movement on bearings that are improperly aligned. Examples of measurements to be taken are shown in Figure 4:4-78. Record the ambient temperature at which the expansion/contraction measurement was taken. Notify the District Engineer or the Inspection Consultant of any severely misaligned bearing or rocker bearing in danger of tipping over during extreme temperatures.

Figure 4:4-77: Reinforced Concrete Box Girder Tight Against the Abutment Backwall With No Room for Further Expansion

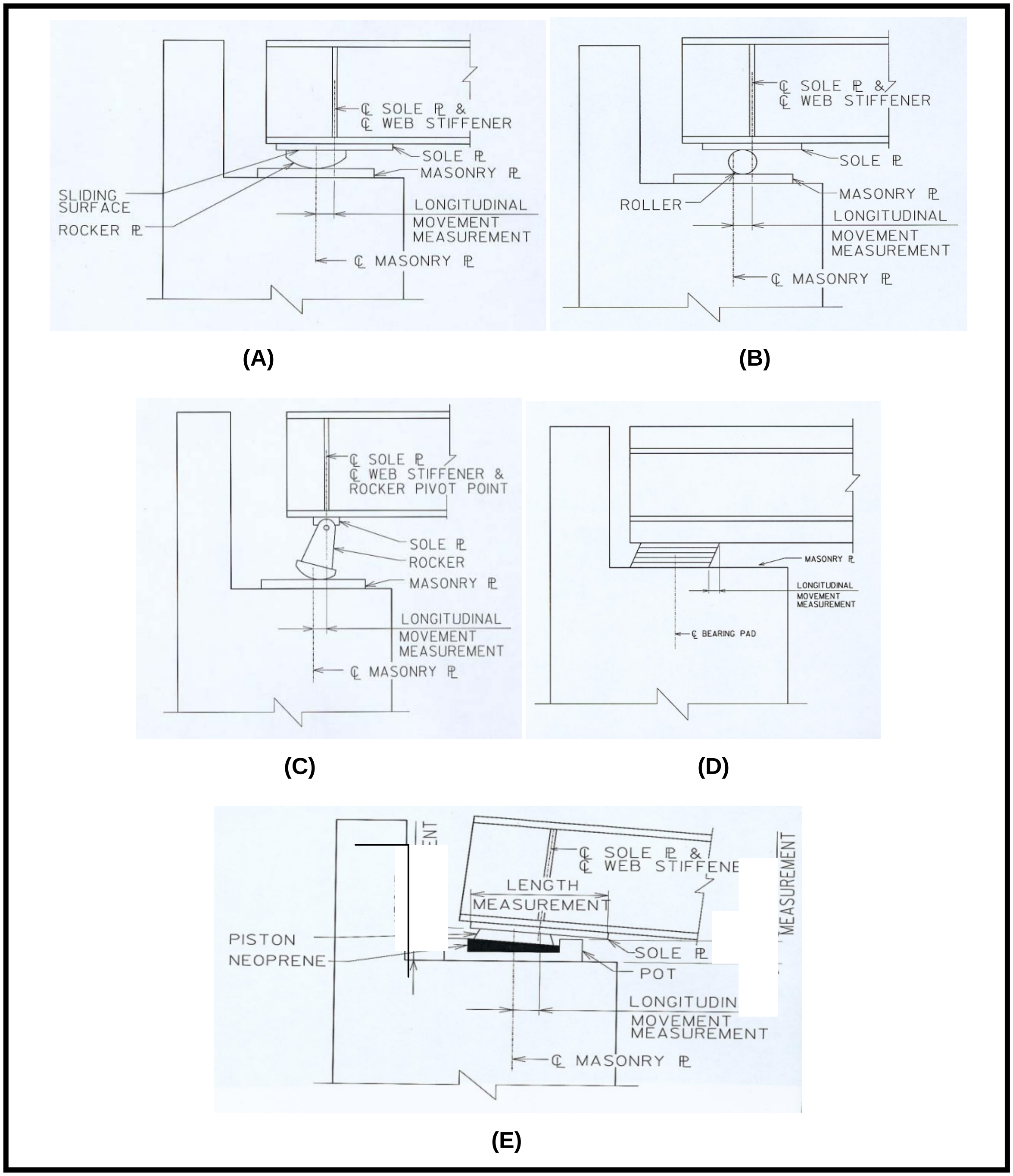
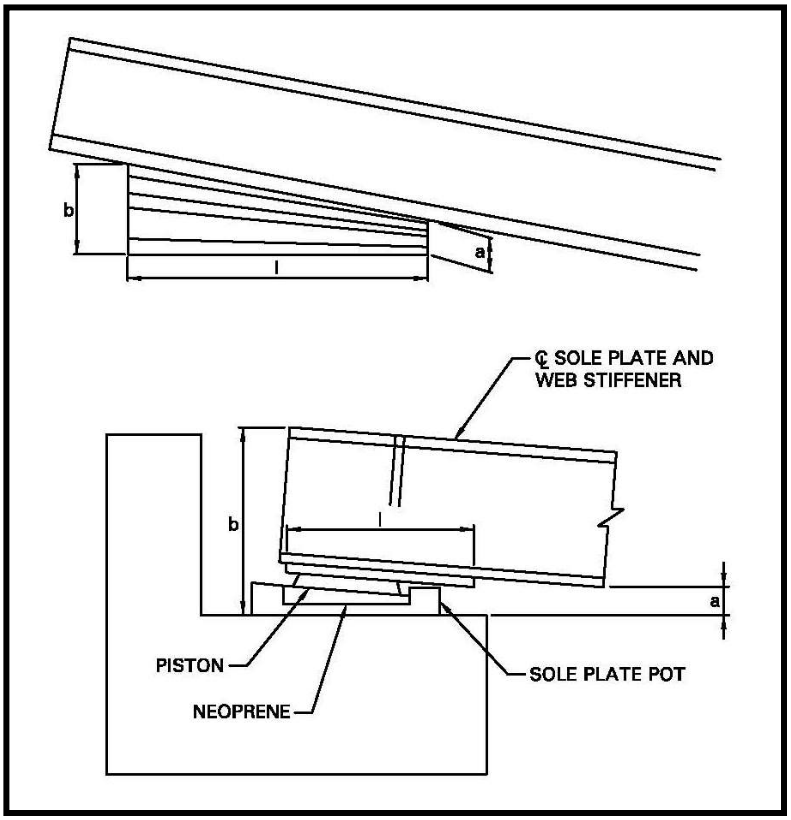


Figure 4:4-78: Longitudinal Movement Measurements

(A) Rocker Plate Bearing
(B) Roller Bearing
(C) Rocker Bearing
(D) Elastomeric Bearing
(E) Pot Bearing

- Measure the height at the front and back of an elastomeric bearing or pot bearing if the rotation is noticeable. Record the height measurements and the length of the bearing. An angle of rotation can then be calculated. The rotation calculation and examples of the measurements to be taken are shown in Figure 4:4-79.



α = bearing rotation in degrees = tan -1((b-a)/l)

Figure 4:4-79: Bearing Rotation Measurement

- Record the ambient temperature at which measurements were taken.
- Check for detachment of the masonry plate or fixed shoe from the substructure.
- Look for bent anchor rods or anchor rods which have risen up above the masonry plate.
- Check for out-of-place bearing pads. Often elastomeric pads with waxed lubricant will walk out from under the beam/girder and should be replaced.
- Note debris that may be hindering movement.
- Check for any broken keeper bars, pintels, or retainer angles.
- Check for missing or loose anchor rod nuts.

- Check the bearing assembly for pack rust between components, or corrosion of the bearing device or anchor bolts.
- Look for full and even contact of all bearing components.
- Look and listen for signs of bearing looseness, such as movement or rattling under live loads, uplift, and loose or missing fasteners/welds.
- Look for signs of proper movement/wear on sliding plates.
- Check for excessive bulging on the sides of the elastomeric pads. Bulging in excess of about 15 percent of the pad’s thickness is a cause for concern.
- Check for any uplift.
- Look for splits or tears in elastomeric pads. These may be oriented vertically or horizontally. Horizontal splits in a laminated pad indicate a serious condition and should be reported.
- Check for variable thickness of the elastomeric pads in the lateral direction, suggesting lateral rocking of the girder. This would be an unusual occurrence and when this happens, look for signs of distress in other parts of the bridge.
- Check for neoprene pad extrusion above the pot rim on pot bearings. This indicates serious distress.

Figure 4:4-80: Bearing Failure

Figure 4:4-81: Elastomeric Bearing With Uplift at the Corner

Figure 4:4-82: Steel Rocker Bearing

Figure 4:4-83: Fixed Shoe Bearing

- Look for wear or binding on guide bars. Guide bars are sometimes used on expansion pot bearings to restrict lateral movements in the transverse direction.
- Check for proper pot bearing alignment. Signs include:
    - A superstructure that is tight against the backwall of the abutment.
    - Exposure of the piston top or top surface of the top aluminum alloy casting.
    - Excessive overhang of the top sliding plate over the piston or top aluminum alloy casting. The top plate and pot should normally line up between temperatures of 60 to 70 degrees Fahrenheit, although this could vary for any individual bridge.
- Look for cracked welds.
- Look for loss of bearing area or deterioration of bearing area.

Figure 4:4-84: Tipped Pot Bearing (Type N)

Figure 4:4-85: Steel Rocker Bearing (Type E)

Note the loss of bearing under the masonry plate in Figure 4:4-85.

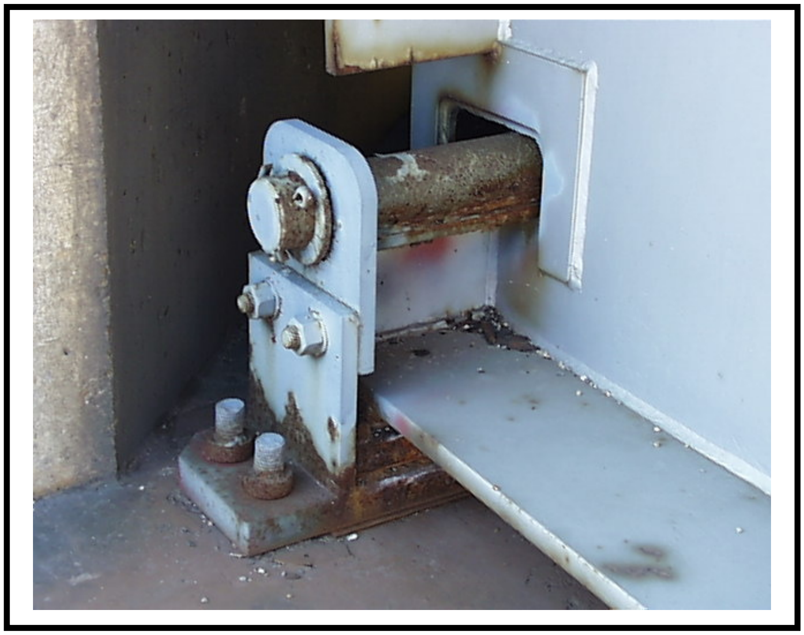


Figure 4:4-86: Hold-Down/Restraining Bearing

Figure 4:4-87: Steel Roller Bearing (Type D)

Note the critical misalignment and distance from the beam to backwall in Figure 4:4-87.

ITEM 59A.01A – BEARING TYPES AT ABUTMENTS

Enter the appropriate code for the bearing type at the abutments. The letter code for different bearing types is shown below. Enter the minimum distance between the abutment/backwall and the end of the beam or girder. Enter the approximate air temperature and the longitudinal movement, as shown in Figure 4:4-78. Enter the angle and direction of movement if applicable.

ITEM 59A.01B – BEARING TYPES AT INTERMEDIATE SUPPORTS

Enter the appropriate code for the bearing type at intermediate supports. The letter code for different bearing types is shown below. Enter the approximate air temperature and the longitudinal movement, as shown in Figure 4:4-78. Enter the angle and direction of movement if applicable.

Code	Bearing Type
A	**None**
B	**Steel Plates**
C	**Steel Curved Plates**
D	**Steel Rollers**
E	**Steel Rockers**
F	**Steel/Bronze Curved Plates**
G	**Steel/Teflon**
H	**Elastomeric – Plain**
I	**Elastomeric – Steel Plate Reinforcement**
J	**Elastomeric – Polytetrafluroethylene (PTFE) Plane**
K	**Spherical**
L	**Stainless Steel Plate**
M	**Resilient, Fiber-Free Pad with Teflon**
N	**Pot**
O	**Disc**
P	**Cylindrical**
T	**Integral**
Z	**Other**

ITEM 59A.01C – SEISMIC RESTRAINTS

There are many types of seismic restraints used in Indiana due to changing codes and thoughts on how to restrain bridges. Check if seismic restraints have been installed.

Figure 4:4-88: Typical Seismic Restraint

ITEM 59A.02 – STEEL GIRDERS

Steel girders have built-up webs and flanges and are generally much deeper than steel beams. These can be built-up either by welding, bolting, or riveting individual members together to make the structural member. They can be used as primary longitudinal or transverse members. When used as floor beams, they are rated under Item 59A.16. Girders often have many welded attachments, including web stiffeners, which can create local areas of stress. Inspection should follow the guidelines detailed in Part 4, Section 4.2, Steel Superstructures. Rate the physical condition of the girders and their ability to function as designed.

Figure 4:4-89: Steel Girder in Good Condition

Figure 4:4-90: Painted-Over Section Loss on Girder Web

ITEM 59A.03 – STEEL BEAMS

Steel beams are considered to be "rolled" members. These can be rolled "I" shapes, channel shapes, or "H" shapes. Beams rated under 59A.03 are used as the primary longitudinal members. When used for stringers or floor beams, they are rated under items 59A.15 and 59A.16. Inspection should follow the guidelines detailed in Part 4, Section 4.2, Steel Superstructures. Rate the physical condition of the steel beams and their ability to function as designed.

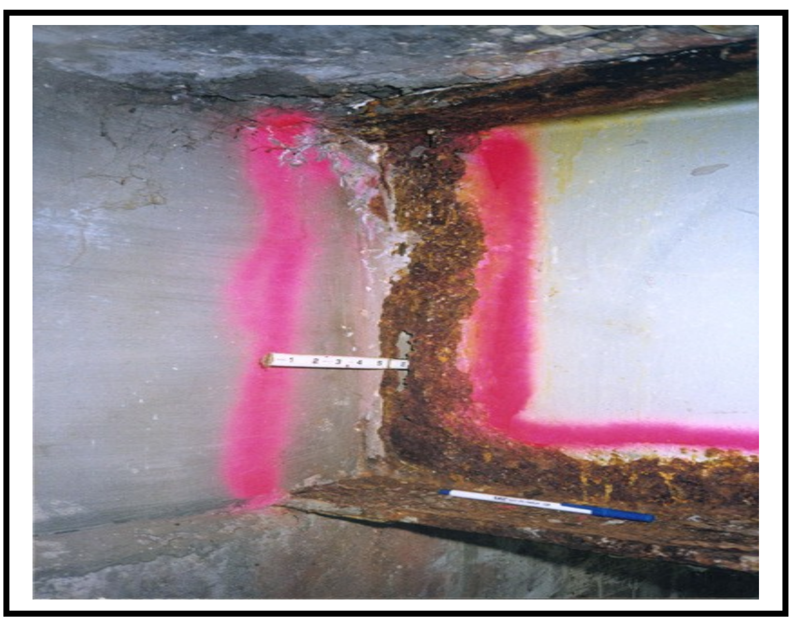


Figure 4:4-91: Steel Beam With Through Thickness Corrosion

Figure 4:4-92: Steel Beam With Through Thickness Section Loss

ITEM 59A.04 – STEEL DIAPHRAGMS

Diaphragms are generally perpendicular to the roadway and provide bracing between the longitudinal girders or beams. Diaphragms are secondary members. Diaphragms include solid diaphragms such as channel sections and I-beams.

Figure 4:4-93: Steel Channel Diaphragms

The inspection of diaphragms should follow the guidelines detailed in Part 4, Section 4.2, Steel Superstructures. Rate the physical condition of the diaphragm and its ability to function as designed. Note the type of diaphragm.

ITEM 59A.05 – STEEL CROSS BRACING

Cross bracings are diaphragms constructed using angles or structural tees. Cross bracings are secondary members. See Items No. 59A.26, 59A.27, 59A.28, and 59A.29 for lateral bracing.

Figure 4:4-94: Steel Cross Bracing

The inspection of steel cross bracing should follow the guidelines detailed in Part 4, Section 4.2, Steel Superstructures. Rate the physical condition of the cross bracing and its ability to function as designed. Note the type of bracing members. Look for out-of-plane bending cracks whenever the cross-bracing is staggered. Look for vertical cracks in the web along vertical web stiffeners and longitudinal cracks in web-flange welds. Look for spider web cracking on back side of the web.

ITEM 59A.06 – CONCRETE GIRDERS

Girders are generally cast-in-place concrete members other than slabs. These are sometimes called Tee Beams in other states. In Indiana, post-tensioned concrete boxes and slabs are also referred to as girders. Inspection should follow the guidelines detailed in Part 4, Section 4.3, Concrete Superstructures. Rate the physical condition of the girders and their ability to function as designed. For reinforced concrete girder bridges in Indiana, the concrete deck is a structural part of the girder.

Figure 4:4-95: Reinforced Concrete Girder Bridge With Minor Rust Staining

Figure 4:4-96: Reinforced Concrete Box Girder With Exposed Steel and Hole

Figure 4:4-97: Reinforced Concrete Box Girder, Bottom Flange, Through Thickness Section Loss

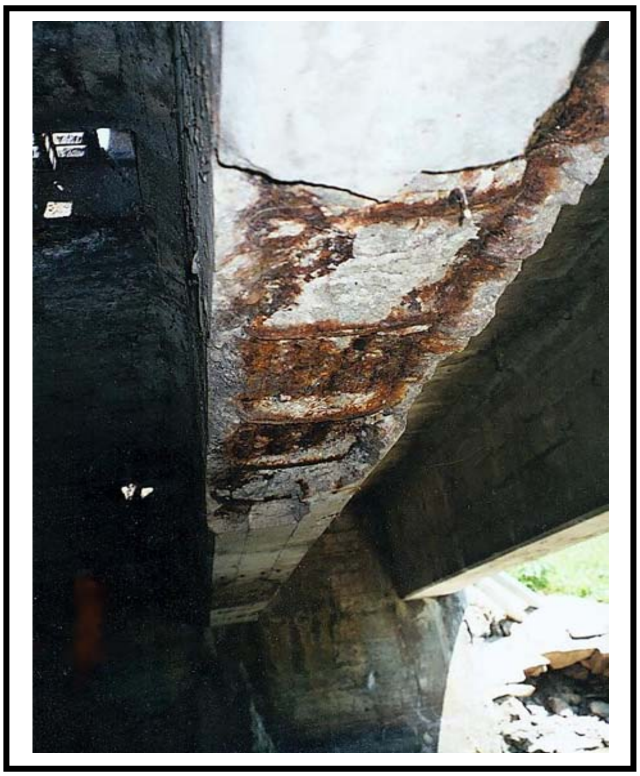


Figure 4:4-98: Reinforced Concrete Girder With Spalling and Steel Section Loss

ITEM 59A.07 – CONCRETE BEAMS

Concrete Beams are precast concrete members. Inspection should follow the guidelines detailed in Part 4, Section 4.3, Concrete Superstructures. Note the type of beam: I-beam, channel beam, T-beam, bulb T-beam, modified bulb T-beam, “U,” or closed box.

Figure 4:4-99: Delaminated and Spalled Precast Beam With Exposed Steel

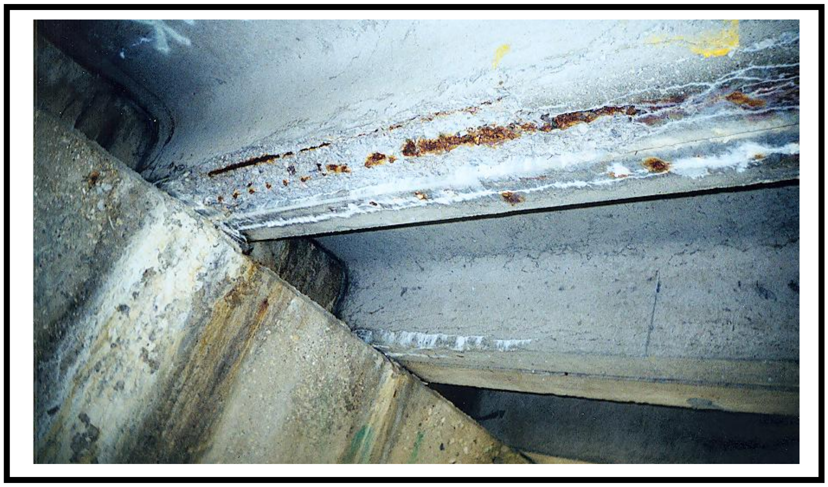


Figure 4:4-100: Prestressed Channel Beams With Exposed Strands, Longitudinal Cracks, Efflorescence, and Rust Staining

Figure 4:4-101: Prestressed Girder With Impact Damage

Figure 4:4-102: Prestressed I-Beams and Diaphragms in Good Condition

ITEM 59A.08 – CONCRETE DIAPHRAGMS

Reinforced concrete diaphragms are secondary members placed transversely between the main load-carrying members. Their cross sections are normally rectangular and are constructed with the bridge deck concrete pour. They are used between both cast-in-place and prestressed beams.

Diaphragms serve several purposes, depending on their location along the span. Intermediate diaphragms are located between the bridge supports. They serve to laterally support the beams and help distribute the live load among them so that they will act as a unit. Diaphragms over piers are considered intermediate diaphragms on continuous spans only.

End diaphragms, also called mudwalls, are located at abutments. Diaphragms are also located at piers under expansion joints. When there are no joints over the piers, these are called integral pier diaphragms or curtain walls. These diaphragms serve to keep the beams' ends in alignment and to strengthen the end of the deck. They act as simple beams transversely spanning between the main members to deliver wheel loads to the bearings.

Rate the overall condition of concrete diaphragms and their ability to function as designed.

ITEM 59A.09 – CONCRETE SLABS

On concrete slab bridges, the deck is also the superstructure, so the rating of the deck and superstructure must be the same. This rating must match the rating for NBI Item 58.

ITEM 59A.10 – CONCRETE SLABS INTEGRAL WITH PIER

Check "Y" (yes) if the slab is constructed integral with the pier cap for interior piers only. Check "N" (no) if not. Integral abutments are covered under Items 60.01, 113 B.02, and 113 B.03.

ITEM 59A.11 – TIMBER SUPERSTRUCTURE

Rate the overall condition as detailed in Part 4, Section 4.4, Timber Superstructure. This rating must match the rating for NBI Item 59.

Figure 4:4-103: Timber Multi-Beam Superstructure

ITEM 59A.12 – ARCHES

Rate the overall condition of all the arch members, including the arch ring, spandrel walls, and columns. This rating must match the rating for NBI Item 59.

Figure 4:4-104: Open-Spandrel Reinforced Concrete Arch (59A.12)

ITEM 59A.13 – ARCH RING

Rate the overall condition of the arch ring.

Figure 4:4-105: Arch Ring

ITEM 59A.14 – SPANDREL WALLS

Rate the overall condition of the spandrel walls.

Figure 4:4-106: Spandrel Walls

ITEM 59A.15 – STRINGERS

Stringers are generally longitudinal members used in conjunction with a floor system in a truss or two-girder bridge. Rate the overall condition of the stringers.

Figure 4:4-107: Floor Beams and Stringers

ITEM 59A.16 – FLOOR BEAMS

Floor beams are generally transverse members used in conjunction with a floor system in a truss or a two-girder bridge. Floor beams and their connections to trusses or two-girder systems may be fracture critical. If there are fracture critical members, they must be inspected at arm's-length. Rate the overall condition of the floor beams.

ITEM 59A.17 – KNEE BRACES

A knee brace is a short member, engaging at its ends two other members that form a right angle or a near right angle to stiffen the connecting joint. Rate the overall condition of the knee braces. Most knee braces in Indiana are located over and under floor beam connections.

ITEM 59A.18 – TRUSSES

Rate the overall condition of the trusses in accordance with Part 4, Section 4.2 for steel trusses and in accordance with Part 4, Section 4.4 for any timber trusses.

Figure 4:4-108: Steel Truss Bridge

ITEM 59A.19 – TRUSS EYEBARS

Check the box marked yes if the truss is constructed using eyebars.

Figure 4:4-109: Truss Eyebars

ITEM 59A.20 – TRUSS VERTICALS

Rate the overall condition of the truss verticals in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

Figure 4:4-110: Built-Up Truss Verticals

ITEM 59A.21 – TRUSS DIAGONALS

Rate the overall condition of the truss diagonals in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

Figure 4:4-111: Truss Diagonals

ITEM 59A.22 – TRUSS UPPER CHORDS

Rate the overall condition of the truss upper chords in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.23 – TRUSS LOWER CHORDS

Rate the overall condition of the truss lower chords in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.24 – UPPER BRACINGS

Rate the overall condition of the truss upper bracings in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.25 – PORTALS

Rate the overall condition of the truss portals in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.26 – TOP LATERALS

Rate the overall condition of the top laterals in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.27 – LATERAL STRUTS

Rate the overall condition of the lateral struts in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.28 – SWAY BRACING

Sway bracing keeps two trusses parallel. Rate the overall condition of the sway bracing in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.29 – LOWER BRACING

Rate the overall condition of the lower bracing in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.T1

Rate the condition of some part of the truss not identified above.

ITEM 59A.T2

Rate the condition of some part of the truss not identified above.

ITEM 59A.30 – CONNECTION PLATES ITEM 59A.30

Rate the overall condition of the connection plates. Note any deformation in any connection plate.

ITEM 59A.31 – GUSSET PLATES

A gusset plate is any plate used to transfer load from one member to another. Rate the overall condition of the gusset plates. Note any cracks or deformation. See Chapter 11, Fatigue and Fracture Critical Inspections.

Figure 4:4-112: Bolted Gusset Plate

Figure 4:4-113: Riveted Gusset Plate

ITEM 59A.32 – STAY/BATTEN PLATES

Stay/batten plates are tie plates or diagonal bracing designed to prevent relative movement between components of a built-up member. Rate the overall condition of the stay or batten plates.

ITEM 59A.33 – LACINGS

Lacings, sometimes called lattice, are small flat plates, usually with one rivet at each end, used to tie individual sections of built-up members. Rate the overall condition of the lacings.

ITEM 59A.34 – RIVETS

Rate the overall condition of the rivets.

Figure 4:4-114: Rivets in Sound Condition

ITEM 59A.35 – BOLTS

Rate the overall condition of the bolts.

ITEM 59A.36 – SPLICE PLATES

Rate the overall condition of the splice plates.

ITEM 59A.37 – BRACKETS

Rate the overall condition of the brackets.

ITEM 59A.38 – TACK WELDS

Rate the overall condition of the tack welds.

ITEM 59A.39 – FULL WELDS

Rate the overall condition of the full welds.

ITEM 59A.40 – OTHERS

Rate the overall condition of other connection details or types. Note the type.

ITEM 59A.41 – HANGERS

Rate the overall condition of the hanger connection system, including pins or U-bolts.

Figure 4:4-115: Hangers on Through-Truss Arch Bridge

ITEM 59A.42 – TOTAL NUMBER OF HANGERS

Enter the total number of hangers or hanger assemblies.

ITEM 59A.43 – HINGES

Rate the overall condition of the hinges.

ITEM 59A.44 – PINS

Rate the overall condition of the pins.

ITEM 59A.45 – TOTAL NUMBER OF PINS

Enter the total number of pins.

ITEM 59A.46 – NUTS

Rate the overall condition of the nuts for the pins.

ITEM 59A.47 – HANGER BARS

Rate the overall condition of the hanger bars, straps, links, or U-bolts.

ITEM 59A.48 – WEB PLATES

Rate the overall condition of the web plates at pin-and-hinges or pin-and-hangers connections.

ITEM 59A.49 – MUDWALLS

Mudwalls, often called backwalls, are the vertical face of the abutment above the bearing seat. Rate the overall condition of the mud walls.

Figure 4:4-116: Mudwall With Efflorescence

ITEM 59A.50 – CURTAIN WALLS

Curtain walls are concrete diaphragms over piers without a joint. They extend down to the pier cap. Rate the overall condition of the curtain walls.

ITEM 59A.51 – COLLISION DAMAGE

Rate the overall condition of any member damaged by collision.

Figure 4:4-117: Collision Damage to Exterior Girder

Figure 4:4-118: Collision Damage

ITEM 59A.52 – ALIGNMENT OF MEMBERS

Rate the overall alignment of the members.

ITEM 59A.53 – DEFLECTIONS

Rate any deflection of the structure.

ITEM 59A.54 – VIBRATIONS

Rate any vibration of the structure.

ITEM 59A.55 – IMPACT

Rate the overall condition of the members damaged by the impact onto and off of the bridge deck by trucks traveling at highway speed.

ITEM 59A.56 – NOISE

Rate any noise made by the structure.

ITEM 59A.OTH1 – ADDITIONAL ITEMS

Describe and rate the condition of any additional items.

ITEM 59A.OTH2 – ADDITIONAL ITEMS

Describe and rate the condition of any additional items.

SECTION 4.8 PAINT AND TONNAGE OF STEEL

Paint acts as a physical barrier between the steel and environment. By preventing oxygen, moisture, deicing chemicals, and pollutants from coming in contact with the steel, the paint coating prevents the rust-producing electrochemical reaction from starting. Two to four paint layers typically make up the coating system and include the prime coat and one or more top coats. On older bridges, the prime coat usually contains lead, easily discerned by its orange/red-orange color in the first or second coat of paint. The paints in newer systems are usually lead-free and impregnated with zinc that acts as an additional level of protection. On painted steel, rust indicates a coating failure.

Weathering steel is not intended to be painted or galvanized. It is intended that it be left exposed to the atmosphere, developing a dense, protective oxide coating. If weathering steel remains wet for extended periods or is exposed to a corrosive atmosphere, the protective oxide coating will not form and the weathering steel will corrode. The signs of corrosion on weathering steel include deep pitting, laminar rust, flaking, or a course texture. If the weathering steel is corroding, rate the paint condition as if the steel was painted and note the type of steel.

ITEM 59B.01 – PAINT

Rate the overall condition of the paint.

- **N** **Not applicable** – no paint or weathering steel
- **9** **Excellent Condition** – recently painted – good seal
- **8** **Very Good Condition** – may be several years since painting; good seal; minor chalkiness
- **7** **Good Condition** – few areas of light rust; some chalkiness and peeling
- **6** **Satisfactory Condition** – light rust in many areas; extensive chalkiness and some peeling
- **5** **Fair Condition** – light rust in many areas with localized areas of medium rust buildup; crackling, peeling, and blistering over a large area
- **4** **Poor Condition** – many areas of medium rust and localized areas of heavy rust; significant peeling, cracking, and blistering
- **3** **Very Poor Condition** – many areas of heavy rust
- **2** **Very Poor Condition** – many areas of extremely heavy rust
- **1** **Total Paint Failure** – large areas of extremely heavy rust; little or no paint remains
- **0** **Total Paint Failure** – large areas of extremely heavy rust; little or no paint remains

Figure 4:4-119: Paint Date and Contract

ITEM 59B.02 – TYPE OF PAINT (PRIMER)

Enter the type of primer used.

Blank – none or not known

Lead

Zinc

Other

ITEM 59B.03 – PAINT SYSTEM

Enter the type of paint system used.

Blank – none or not known

Three-coat system

Two-coat system

Other

ITEM 59B.04 – PAINT COLOR

Enter the color of the top coat.

Blank – none or not known

Blue

Green

Silver

Red

Pink

Orange

ITEM 59B.05 – ESTIMATED REMAINING LIFE OF PAINT AND PAINT YEAR

Enter the estimated remaining life of the paint. Enter the month and year when the entire superstructure was painted. This date should be painted on the superstructure. If portions were painted after this date, this should be noted in a comment.

ITEM 59B.06 – PAINT CONTRACT NUMBER

Enter the paint contract number.

ITEM 59B.07 – WEATHERING STEEL

Enter whether weathering steel was used or not.

Blank – none or not known

Y – weathering steel was used

N – weathering steel was not used

ITEM 59C.01 – TONS OF STEEL

Enter the tons of steel used in the superstructure. Note the square footage of steel, if this has been calculated. Document all quantities from the last painting contract for future work.

OTHER COATINGS AND SEALANTS

Enter the type and condition of any coatings and sealants that are not paint.